Quick-fit Method for Assessing Quality of Fabrics used for Home-made face Masks- Lusaka Zambia

James Nyirenda* and Onesmus M. Munyati
The University of Zambia, School of Natural Sciences,
Department of Chemistry, P.O. Box 32379, Lusaka, Zambia
Contact James Nyirenda nyirendaj@unza.zm The University of Zambia, School of Natural Sciences, Department of Chemistry, P.O. Box 32379, Lusaka, Zambia

Abstract

The study investigated the quick, non-standard informative test method for assessing the quality of fabrics intended for making facemasks. Highly efficient N95 facemasks are costly in Zambia (about US$ 1.20) hence the need for cheap alternative facemask materials. Various materials were tested for filtration efficiency, breathability and effect of washing and ironing on these parameters. Filtration efficiency and breathability for monolayer-unwashed showed from highest to lowest; Java (98.00±1.40%,16754.7Pa/cm^2), Telela (12.20±1.0%, 18.9 Pa/cm^2); monolayer-washed; Cotton(200) pillow-case (87.1±0.1%,217Pa/cm^2),Telela (16.5±0.1%,75.5Pa/cm^2). Bilayer-unwashed; Java (99.7±0.1,25669.8Pa/cm^2), Telela (59.5±3.5,47.2Pa/cm^2), bilayer-washed and ironed; Java (99.7±0.1%,11603.8Pa/cm^2), Telela (61.0±1.0%,113.2 Pa/cm^2). The plain-inner with outer-honeycomb combination, was; grey (59.2±1.0%,150.9Pa/cm^2) , black (52.8±0.8%,245.3Pa/cm^2), yellow-khaki (99.3±0.3%, 490.6Pa/cm^2) and stiffener (46.1±0.1%,18.9Pa/cm^2). Results show that fabrics available are suitable for fabricating masks. Filtration efficiency increased while breathability remained within appreciable values compared with the reference. Washing and ironing had no significant effect on monolayers. Significance (p=0.0006) was shown when monolayer and bilayer fabrics were compared.

Keywords: Face mask, SARS-CoV-2, Covid-19, breathability, pressure drop

Introduction

Following the outbreak of the coronavirus (SARS-CoV-2 or COVID-19) disease in December 2019 in Wuhan China, the virus has since spread to all continents and fatalities have crossed the two million cumululative figure as of January 2021. The demand for disposable surgical face masks globally is higher than the supply hence in many countries such masks are being reserved for frontline staff. Due to this, there has been an increased need for mass production of homemade masks to meet the demand globally. The standards for testing materials meant for face masks from clothing material seem not to be well established probably due to the diverse fabrics on the market. A non-medical mask standard has been developed by the French Standardisation Association (AFNOR Group), to define minimum performance in terms of filtration (minimum 70 per cent solid particle filtration or droplet filtration) and breathability (maximum pressure difference of 0.6 mbar/cm^2 (49 Pa/cm^2)or maximum inhalation resistance of 2.4 mbar and maximum exhalation resistance of 3 mbar) (Veritas, 2020). Wearing masks is one of the key intervention methods in the spread of the SARS-CoV-2 viral disease as demonstrated by Dr. Wu (L. G. Goh, 1987). Wu Lien Teh's work to control the 1910 Manchurian Plague has been acclaimed as "a milestone in the systematic practice of epidemiological principles in disease control, in which Wu identified the cloth mask as "the principal means of personal protection." Although Wu designed the cloth mask that was used through most of the world in the early 20th century, he pointed out that the airborne transmission of plague was known since the 13th century, and face coverings were recommended for protection from respiratory pandemics since the 14th century. Wu reported on experiments that showed a cotton mask was effective at stopping airborne transmission, as well as on observational evidence of efficacy for health care workers. Masks have continued to be widely used to control transmission of respiratory infections in East Asia through to the present day, including for the COVID-19 pandemic (Howard *et al.*, 2021). The basic principle in wearing the masks is to prevent transmission of the virus through droplets that are released during the normal respiratory process, laughing, coughing or sneezing. Clothing material is commonly used to make homemade masks. The properties of fabrics are intended to meet a variety of requirements of the primary purposes that they are manufactured for (Veritas, 2020). The porosity or fabric mesh is one key characteristic of interest in assessing the suitability of the fabric used as a face mask material because it will determine the ability of the cloth to prevent particles of a specific size to pass through. The other quality is thread count where fabric of 180 or more thread counts per inch(tpi) or 25.4 mm are considered high quality in terms of density(Raheja, 2020). Still another quality is comfort to the user(Asanovic *et al.*, 2016), hence the need to carefully select material that meets as many qualities as possible. The use of disposable faces masks is, however, a potential threat to environmental damage (Allison *et al.*, 2020) due to their being non-degradable. (Selvaranjan *et al.*, 2021), conduted a review in which levels of plastics were quanitified based on assumptions of minimal use of 1 to maximal use of 5 and found to be in millions of tonnes per week thereby posing a disposal challenge as the majority of the face masks used were non-woven fabric surgical masks which, according to this study, were a preferred choice based on performance. The use of face masks in public, indoor, and outdoor settings, although considered as a passive measure additional to others (e.g. social distancing, hand washing), has been widely recommended by public health authorities during the current COVID-19 pandemic, especially when social or physical distancing is not technically possible, to mitigate the risk of infection via respiratory droplets (Santarsiero *et al.*, 2020a). However, available studies and guidelines are rather generic and conflicting when they come to denominating the masks (i.e. commercial fabric/cloth and homemade mask etc.), the parameters that measure their performance, and the materials they are made of. Common fabrics (natural or synthetic) (Santarsiero *et al.*, 2020a) are alternative materials to Non-Woven Fabrics (NWFs) of which Medical devices (MDs) and respiratory Personal Protection Equipment (PPE) are usually made. NWF mainly consists of polypropylene (PP), rarely of Polyethylene Terephthalate (PET) or polyamide. Other materials used to make masks include polymers like polystyrene, polycarbonate or polyester (Abbasi *et al.*, 2020).The predominant use of PP for MDs and respiratory PPE is due to technological, marketing factors, and, perception that they offer better protection against viral and bacterial infections (Chua *et al.*, 2020, Garcia, 2020, Howard *et al.*, 2021, Selvaranjan *et al.*, 2021). Polypropylene is one of the cheapest polymers on the market and one of the most easily spinnable to micron size, which is a prerequisite to achieve good filtering properties. Masks made of synthetic NWF mostly consist of three or more layers (Selvaranjan *et al.*, 2021, Santarsiero *et al.*, 2020a). The outermost layer of the mask, usually made of spunbond NWF with a hydrophobic treatment, is inexpensive, light, and provides mechanical strength and functional properties to the mask. (Santarsiero *et al.* 2020b), further stated in their paper that available studies on both commercial and homemade fabric or cloth masks do not sufficiently describe the structure of the masks, so as to be able to characterise them from the point of view of properties and performance. One comparison factor, which is currently being studied by many research groups undertaking testing fabric quality, is the filtration quality factor q_f (Huang *et al.*, 2013, W.H.O, 2020, Santarsiero *et al.*, 2020b)(equation 1)

$$q_f=\ln(1/P)/\Delta p \quad (1)$$

where P is the fraction of aerosol penetration and **Δp** is the pressure drop across the filter (Huang *et al.*, 2013).

Materials and methods

Cloth material fabrics were purchased locally from retail shops as well as malls around Lusaka. PVC piping and pressure gauges were purchased from local hardware shops
The testing procedures used were non – standard procedures adapted to provide sufficient data to inform on the filtration efficiency and breathability of the masks. Experiments were carried out on 7 selected materials purchased from local shops. Charcoal, as a visual standard, was also sourced from a commercial outlet. The digital Comark C9555 was sourced from the Department of Mechanical Engineering, at the University of Zambia.

Results and Discussion

Insightful data has been presented in this article on 7 selected materials that were presented for assessment for mono and bilayer combination as well as 3 materials meant as a combination of plain inner cotton and embossed outer cover. Also tested on filtration efficiency was one fabric stiffener under normal and ironed conditions. It has shown the extent to which the different fabrics are able to limit the passage of particles of 38 microns through the fabric. Therefore, it can be inferred that respiratory droplets that are 38 microns or more may not pass through. The interpretation is valid only in application at laboratory test scale and may not be valid at the point of actual use due to variations in designs and correct use of the mask. Although Java had the highest filtration efficiency (98.00±14%), it also had a high-pressure drop (0.8880 bar). The higher the pressure drop the more uncomfortable the breathing would be to the user of a mask made out of the fabric.

Testing for filtration efficiency (Particle retention)

Preparation of test particles

Pieces of charcoal were pulverised and sieved to 0.038 millimeters (38 microns) consistency using the standard 0.038 mm sieve (Twente).

A predetermined amount of powder comprising 38 micron particles was measured and placed on a 30 cm x 30 cm cloth test sample. The material and the powder were placed in the sieving apparatus and shaken for 20 minutes. The amount of powder that passed through the fabric was measured to quantify the amount that had been retained on the cloth. Three samples of each material were tested and the average values determined.

(a) (b)

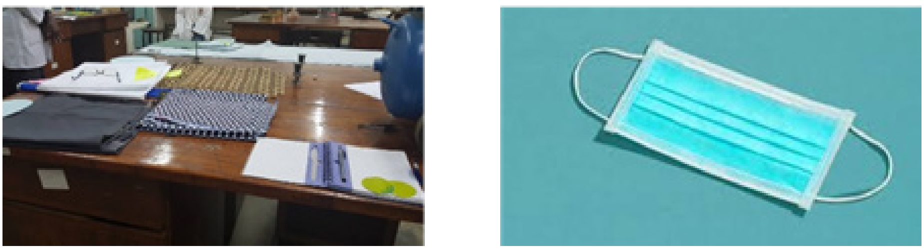

Figure 1: Panel (a) shows the clothing material cut to 30 cm x 30 cm for filtration tests. Panel (b) shows the standard face mask used as a reference for comparing results

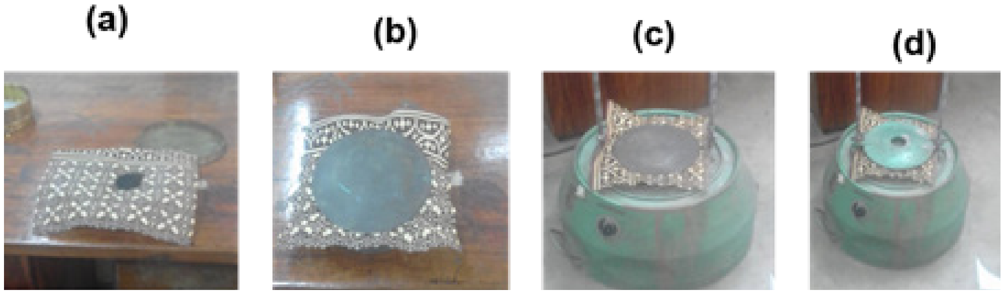

Figure 2: Shows step-wise assembly of the material for filtration. (a) loading a preweighed sample of charcoal powder on sieve placed on the receiving pot, (b) securing the cloth material with tight fitting sieve cover, (c) loading on sieve shaker and (d) securing top lid with screws for onset of vibration at maximum speed for 20 minutes.

Air permeation – pressure drop measures

An experimental setup was constructed that would enable the determination of the change in air pressure after the air has passed through the material at 1 bar. Circular pieces of material measuring 35 mm in diameter were cut from each of the fabrics. The sample material was placed on the sample hold on the test device, the pressure was allowed to equilibrate at 1 bar and the change in pressure after the air has gone through the material was recorded.

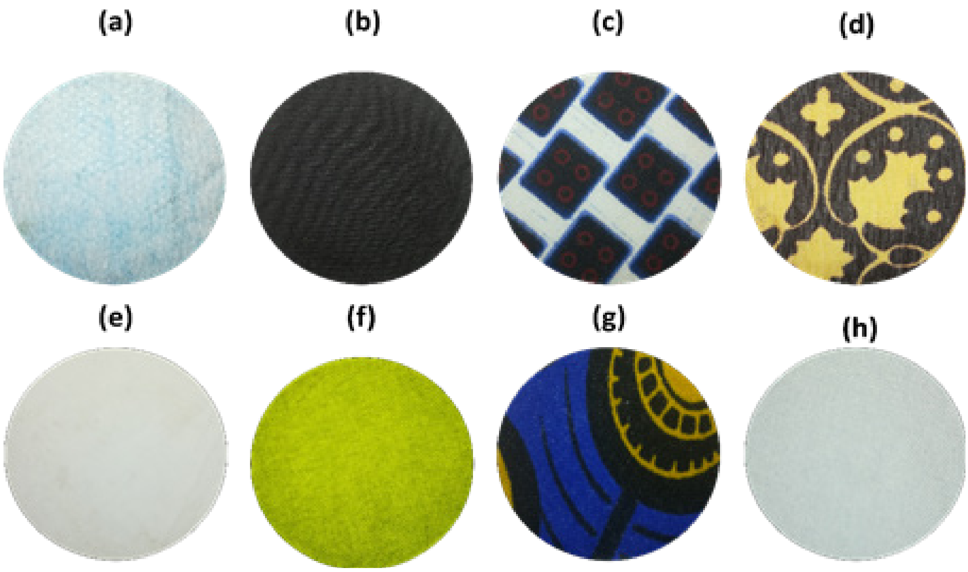

Figure 3: Shows 35 mm cloth discs cut for the breathability test. (a) standard face mask, (b) cotton (200 tpi), (c) poly waxed chitenge, (d) telela chitenge, (e) pure Egyptian cotton (180 tpi), (f) java waxed chitenge, (g) waxed cotton chitenge and (h) pure cotton (180 tpi). The materials were subjected to mono and bilayer tests including the washing and iron tests.

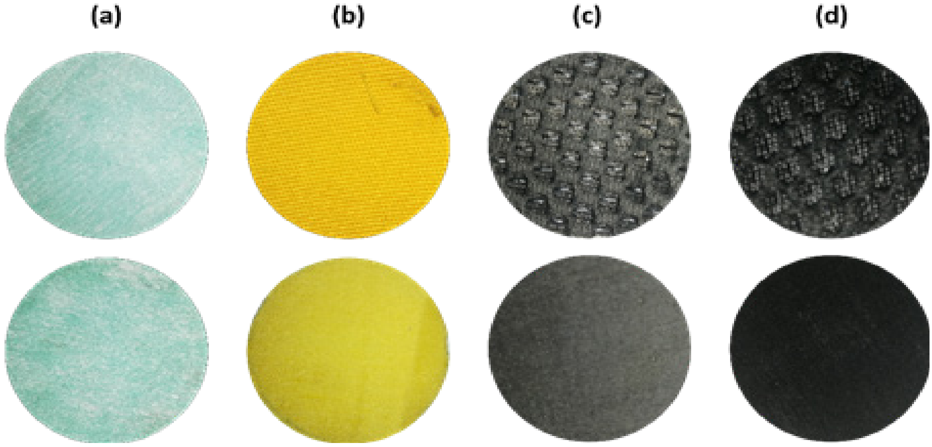

Figure 4: Shows material that was tested as a combined set without monolayer testing. Panel (a) the top shows washed un ironed and the bottom shows washed and ironed fabric stiffener,(b) the top shows thick yellow khaki outer decorative part and the bottom shows plain yellow light cotton inner face mask fabric, (c) the top shows grey honeycomb polyester decorative outer cover and the botton plain grey cotton inner face mask fabric, (d) and the top shows black honeycomb polyester decorative outer cover and the bottom shows plain black inner cotton face mask fabric respectively.

The breathability testing rack was made from low cost plumbing 25 mm polyvinylchloride (PVC) piping able to withstand pressure up to 80 mm/Hg and temperatures of 100 ^{O}C. A compressor was used to deliver consistent amount of air under the control of an exit valve set at 100000 Pa and verified downstream on the rack by two gauges, upstream to read incoming air pressure and downstream to read air pressure after the test rack.

Figure 5: Shows the breathability test rig with an online Comark C9555 Dry-Use differential pressure meter calibrated to read pressure within 0-to-±210000 Pa. Upstream and down stream pressure gauges to verify pressure change before and after the cloth disc holder.

Table 1: Filtration efficiency, pressure drop, breathability and filtration quality factor results for the monolayer unwashed fabrics

No	Sample	Filtration Efficiency (%)	Pressure drop (Pa)	Breathability (Pa/cm^2)	FQF (kPa^{-1})
1	Cotton (200) pillow case	84.4 ± 3.1	900	169.8	4.8±0.1
2	Egyptian cotton (180)	61.9 ± 0.4	300	56.6	13.5±0.9
3	Java	98.0 ± 1.4	88800	16754.7	0.16±0.0
4	Pure cotton (180)	47.0 ± 0.8	1500	283.0	2.6±0.3
5	Telela	12.2 ± 1.0	100	18.9	25.2±0.7
6	Waxed cotton	37.7 ± 0.5	1000	188.7	3.6±0.2
7	Waxed poly cotton	43.3 ± 1.4	950	179.2	3.8±0.2
8	Reference (Surgical mask)	99.8 ± 3.5	200	37.7	23.1±1.0

Table 1: Shows data obtained showing the filtration efficiency and pressure drop for selected monolayer unwashed fabrics (figure 3).

The data shown in Table 1 is presented for the monolayer fabrics. The filtration efficiency reflects the ability to prevent particles that are greater than 38 microns from passing through a single layer of material. Hence filtration efficiency in this study was expressed as a per cent of the retained material. Both retained and flow through material were compared to compute the result. The highest efficiency was recorded for the Java material at 98.00±1.40 per cent whilst the lowest was 12.20±098 per cent for Telela material. The Java material was followed by the cotton (200) pillowcase, Egyptian cotton(180), pure cotton(180), waxed poly-cotton, waxed cotton and Telela. Pressure drop is calculated as the differential pressure between the high pressure inlet and low pressure outlet using pressure gauges in fluid flow studies. The drop in pressure shows how easy or difficult it is for air to pass through a filter. Therefore, it also gives an indication of how easy or difficult it may be to breathe through the material. With these results, the highest pressure drop recorded was for Java at 88800 Pa translating to a breathability of 16754.7 Pa/cm^2. This could have been as a result of the wax layer on the fabric and also fabric thread count among other reasons. The lowest pressure drop was recorded for the fabric sample Telela (100 Pa), which was closer to the standard disposable facial mask at 37.7 Pa/cm^2. With these results, it was partially concluded that Telela offers good breathability (18.9 Pa/cm^2) compared to other fabrics though under a single layer its filtration efficiency was very low (12.20±1.0%).

Table 2: Filtration efficiency, pressure drop,breathability and filtration quality factor results for the monolayer washed fabrics

No	Sample	Filtration Efficiency (%)	Pressure drop (Pa)	Breathability (Pa/cm^2)	FQF (kPa^{-1})
1	Cotton (200) pillow case	87.1±0.1	1150	217.0	3.8±0.1
2	Egyptian cotton(180)	62.3±0.1	500	94.3	8.3±0.3
3	Java	75.2±2.8	8000	1509.4	0.5±0.1
4	Pure cotton(180)	49.2±0.1	600	113.2	6.4±0.3
5	Telela	16.5±0.1	400	75.5	7.2±0.3
6	Waxed cotton	39.9±0.1	400	75.5	9.2±0.3
7	Waxed poly cotton	44.3±0.1	1400	264.2	2.9±0.2
8	Reference (Surgical mask)	99.8±3.5	200	37.7	23.1±1.0

Table 2: shows results for the monolayer fabrics after washing and testing for filtration and breathability

From the results in table 2, the filtration efficiency for Java changed from 98.00 per cent to 75.2 per cent after washing. The pressure drop also changed from 88800 Pa to 8000 Pa. However, comparing the whole set and using the paired t-test at 95 per cent confidence level showed that there was no significant change induced by washing and ironing (p=0.7) in filtration efficiency and breathability (p=0.4).

Two pieces of the fabric of the same size were loosely put together without any adhesive in between to simulate a double layer mask. The results obtained are shown in table 3.

Table 3: Filtration efficiency, pressure drop,breathability and filtration quality factor results for the bilayer unwashed fabrics

No	Sample	Filtration Efficiency (%)	Pressure drop (Pa)	Breathability (Pa/cm^2)	FQF (kPa^{-1})
1	Cotton (200) pillow case	99.6±0.4	5750	1084.9	0.8±0.1
2	Egyptian cotton(180)	99.5±0.1	1800	339.6	2.6±0.1
3	Java	99.7±0.1	136050	25669.8	0.04±0.0
4	Pure cotton(180)	99.4±0.2	1500	283.0	3.1±0.0
5	Telela	59.5±3.5	250	47.2	16.8±0.5
6	Waxed cotton	91.8±0.1	1150	217.0	3.9±0.1
7	Waxed poly cotton	97.9±0.1	950	179.2	4.8±0.1
8	Reference (Surgical mask)	99.8±3.5	200	37.7	23.1±1.0

Table 3 shows results of the filtration efficiency and breathability under unwashed conditions for the bilayered fabrics. The largest increase was recorded in the Java material whilst the lowest was in the Telela. There was a significant increase in the filtration efficiencies of all the materials (p=0.0033, 95% cl) when the unwashed monolayer fabrics were compared to the unwashed bilayer fabrics. The washed and ironed fabrics showed a further significance (p=0.0006, 95% cl). The increase in the filtration efficiency was accompanied by an increase in the pressure drop. The other significant increments were for the cotton (200) pillow case, and Egyptian cotton(180) fabrics. The apparent increase in filtration efficiency, after ironing, could have been due in part to fabric pores being partly closed up due to heating that could have annealed fibres, and also the partial film resulting from wax reannealing on the fabrics after partial break up by the detergent effect for fabrics having a wax layer.

Table 4: Filtration efficiency, pressure drop,breathability and filtration quality factor results fo the bilayer, washed and press ironed fabrics

No	Sample	Filtration Efficiency (%)	Pressure drop (Pa)	Breathability (Pa/cm^2)	FQF (kPa^{-1})
1	Cotton (200) pillow case	99.3±0.1	1150	217.0	3.8±0.1
2	Egyptian cotton(180)	98.9±0.1	2350	443.4	1.9±0.1
3	Java	99.7±0.1	61500	11603.8	0.1±0.0
4	Pure cotton(180)	99.5±0.1	2450	462.3	1.9±0.1
5	Telela	61.0±1.0	600	113.2	6.9±0.2
6	Waxed cotton	90.9±0.1	1400	264.2	3.2±0.1
7	Waxed poly cotton	97.9±0.1	1100	207.5	4.1±0.0
8	Reference (Surgical mask)	99.8±3.5	200	37.7	23.1±1.0

Table 4 shows results of the washed and presss ironed bilayer fabrics. Compared with the standard surgical mask at 99.8±3.5 per cent, Java had the highest filtration efficiency at 99.7±0.1 per cent. Telela was the least but with a breathability only comparable to the standard surgical mask. Moreover, filtration efficiency improved five times for the addition of one layer for Telela under unwashed conditions. The other materials maximal improvement was only twice the monolayer efficiency. The cotton (200) pillow case as well as the Egyptian cotton (180) reduced in breathability quality six times after one layer was added. Java material decreased eight times making it very difficult to make face masks with both nominal filtration efficiency with breathability compared to the standard surgical mask. However, the breathability was not affected by washing and ironing (p=0.3, 95% cl) when the bilayered fabric set was analysed.

(a)

(b)

Figure 6 : Shows the variations in design and material of home-made bilayered face masks on the Zambian market. Panel (a) shows the face mask in an extended form and panel (b) shows the relative shape after folding to mimic wearers cover space.

Clearly, figure 6 shows inconsistencies even from the same manufacturer. The lack of a standard also means it becomes very difficult to make agreements on which material or design to use because no size fits all due to a large variation in facial structural differences among the population of Zambia.

Table 5: Filtration efficiency, pressure drop,breathability and filtration quality factor results for the monolayer with outer embossed cover

No	Sample	Filtration Efficiency (%)	Pressure drop (Pa)	Breathability (Pa/cm^2)	FQF (kPa^{-1})
1	Black	52.8±0.8	1300	245.3	3.1±0.2
2	Grey	59.2±1.0	800	150.9	5.1±0.3
3	Yellow	99.3±0.3	2600	490.6	1.9±0.1
4	Stiffener	46.1±0.1	100	18.9	38.5±1.1
5	Reference (Surgical mask)	99.8±3.5	200	37.7	23.1±1.0

Table 5 shows the resuts of a set that was purely tested as unwashed and pseudo bilayered as well as ironed stiffener material. A careful physical inspection of the stiffener showed that the grain pattern was affected by heat but the material is largely porous even under heating at the maximal pressing iron temperature level. Ironing was done by sandwhiching the material in non stick cotton (200) pillow case material to mimic the actual fabric stiffening.

To fully appreciate the scientific and technological approach, there is need for standards bureau to document all fabrics with respect to the material used as well as thread per inch where applicable. Availability and afforadability needs to be established because most of the materials used in this study were imported fabrics, hence there textural properties were difficult to get. As most of the materials could not meet the 49 Pa/cm^2 (0.6 mbar/cm^2) maximal breathability(WHO, 2020), it may be imperative to re-look at this parameter for many studies to come to a favourable conclusion if majority of fabrics not originally intended for face mask material need to be considered as a proxy. Also different reporting formats for most of the parameters need to be harmonised to avoid confusion or incorrect decision making for particular fabrics.

Some of the limitations to this study included the lack of funds to purchase a particle generator for assessing a wide range of particles to mirror bacteria and viral particles. The lack of particle generators and standard equipment for carrying out tests on fabrics in resource limited countries means innovative cheap means of assessing quality of fabrics need to be encouraged. Hence, this simple rig can act as an interim for mass tests of fabrics. Looking at the sizes of common micro organisms used for testing filtration efficiency(Wilkes *et al.*, 2000, Wilkes, 2002), it is imperative that more testing facilities offering cheap services be made available so as to screen fabrics that should meet minimal criteria as set by the World Health Organisation (WHO, 2020) as well as Centres for Disease Control and Prevention (Adams, 2020). It is recommended that elaborate tests, such as those reported by Drewnick et al (Drewnick *et al.*, 2021), be employed as long as the cost of test equipment is made affordable in resource limited countries.

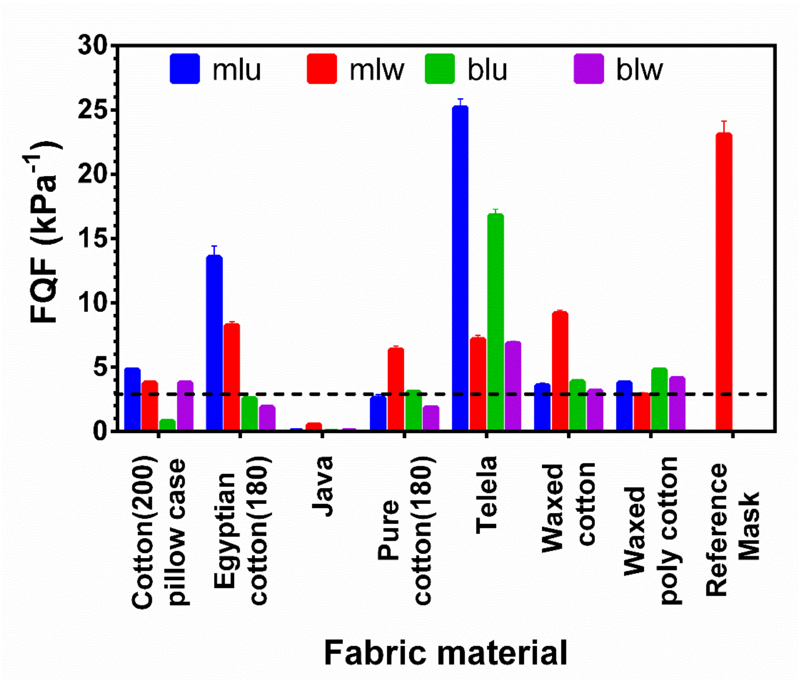

Figure 7 :Filtration Quality Factor (FQF) of various pieces of fabric tested.

Figure 7 shows the filtration quality factor of the test fabrics. mlu; monolayer unwashed, blu; bilayer unwashed, mlw, monolayer washed and ironed and blw; bilayer washed and ironed. The horizontal dashed black line shows the threshold of FQF of 3.0 for consideration as material combinations that may offer good performance (WHO, 2020, Santarsiero *et al.*, 2020b, Konda *et al.,* 2020).

Much as FQF is a factor under study in many studies dealing with quality of fabrics for use as face mask material, (Santarsiero *et al.*, (2020b), opined that there is need for more studies to ensure this factor is more universal to avoid uncertainity in reporting. There was no significant difference in the FQF values between monolayer unwashed and monolayer washed samples (p=0.2) as well as bilayer washed and unwashed (p=0.1). However, comparing the unwashed monolayer and bilayer fabrics showed a significant difference in FQF values (p=0.006). Washing had no overall effect on the FQF parameter for the monolayer and bilayer fabrics (p=0.003).

Jung et al., (2014) have shown that different protocols have shown different values on the same parameters for the same fabric(Jung *et al.*, 2014). An important observation is that fabric not originally intended for fabrication of face masks showed filtration efficiencies that varied greately over 40 to 90 per cent (Rengasamy *et al.*, 2010). To be more universal, it is important to consider many factors before setting up standards for fabric used to make quick and do-it-yourself face masks as many fabrics may fail to pass if only one standard or one parameter is highlighted. Zambia being a developing country may not have enough infrastructure needed to set up testing facilities for fabrics.

It should be noted that the fabrics that were tested in this study were not subjected to elaborate test methods according to the approach by (Drewnick *et al.*, 2021, Wilkes *et al.*, 2000, Konda *et al.,* 2020) as these required well established laboratories with particle size generators.

4.0 Conclusion and Recommendations

Seven different fabric materials were evaluated to determine the extent to which particles that are 38 microns can be prevented from passing through. Therefore, the results presented allows relative effectiveness of the materials in stopping the passage of particles of that size. Modelled against the droplet size of about 38 microns, it was assumed that when used properly, as face mask material, various fabrics on the market may reduce risk of exposure to respiratory infections. It should, however, be noted that pre-conditioning and post-treatment such as washing may affect the characteristics of the fabrics such as thread integrity, colour fastness and pore size change for those fabrics, which may contain starching agents or wax material. The breathability provides information on the comfort the user may experience with the mask. Fabrics with large pressure drops will generally need the wearer to put more effort on breathing in especially for a tight-fitting mask. The great effort in breathing could lead to negative pressure resulting in leakages as well as partial oxygen deficiency and ultimately may lead to asphyxiation. Within experimental limits and also wider consideration of wearers comfort, altitude and material availability, fabrics not intended as face mask materials can be selected based on FQF, breathability, filtration efficiency, as well as comfort of the user.

REFERENCES

Abbasi, S. A., Khalil, A. B. and Arslan, M. 2020. Extensive use of face masks during COVID-19 pandemic:(micro-) plastic pollution and potential health concerns in the Arabian Peninsula. *Saudi Journal of Biological Sciences,* 27**,** 3181-3186.

Adams, J. 2020. Recommendation regarding the use of cloth face coverings, especially in areas of significant community-based transmission.

Allison, A. L., Ambrose-Dempster, E., T Aparsi, D., Bawn, M., Casas Arredondo, M., Chau, C., Chandler, K., Dobrijevic, D., Hailes, H. and Lettieri, P. 2020. The environmental dangers of employing single-use face masks as part of a COVID-19 exit strategy.

Asanovic, K. A., Cerovic, D. D., Mihailovic, T. V., Kostic, M. M. and Reljic, M. 2016. Quality of clothing fabrics in terms of their comfort properties. *Indian Journal of Fibre and Textile Research (IJFTR),* 40**,** 363-372.

Chua, M. H., Cheng, W., Goh, S. S., Kong, J., Li, B., Lim, J. Y., Mao, L., Wang, S., Xue, K. and Yang, L. 2020. Face masks in the new COVID-19 normal: materials, testing, and perspectives. *Research,* 2020.

Drewnick, F., Pikmann, J., Fachinger, F., Moormann, L., Sprang, F. and Borrmann, S. 2021. Aerosol filtration efficiency of household materials for homemade face masks: Influence of material properties, particle size, particle electrical charge, face velocity, and leaks. *Aerosol Science and Technology,* 55**,** 63-79.

Garcia, L. P. 2020. Use of facemasks to limit COVID-19 transmission. *Epidemiologia e Serviços de Saúde,* 29**,** e2020023.

Howard, J., Huang, A., Li, Z., Tufekci, Z., Zdimal, V., van der Westhuizen, H.-M., von Delft, A., Price, A., Fridman, L. and Tang, L.-H. 2021. An evidence review of face masks against COVID-19. *Proceedings of the National Academy of Sciences,* 118.

Huang, S.-H., Chen, C.-W., Kuo, Y.-M., Lai, C.-Y., McKay, R. and Chen, C.-C. 2013. Factors affecting filter penetration and quality factor of particulate respirators. *Aerosol and Air Quality Research,* 13**,** 162-171.

Jung, H., Kim, J. K., Lee, S., Lee, J., Kim, J., Tsai, P. and Yoon, C. 2014. Comparison of Filtration Efficiency and Pressure Drop in Anti-Yellow Sand Masks, Quarantine Masks, Medical Masks, General Masks, and Handkerchiefs. *Aerosol and Air Quality Research,* 14**,** 991-1002.

Konda, A., Prakash, A., Moss, G. A., Schmoldt, M., Grant, G. D. and Guha, S. 2020. Aerosol filtration efficiency of common fabrics used in respiratory cloth masks. *ACS nano,* 14**,** 6339-6347.

L. G. Goh, T. H., K. H. Phua 1987. Wisdom and western science: The work of Dr Wu Lien-Teh. . *Asia Pacific Journal of Public Health* 1**,** 99-109.

Raheja, A. 2020. *Comparison of High Thread Count Cotton Fabrics for Comfort and Mechanical Properties* [Online]. Available: https://textilelearner.net [Accessed 03 05 2021 09:22 CAT 2021].

Rengasamy, S., Eimer, B. and Shaffer, R. E. 2010. Simple respiratory protection—evaluation of the filtration performance of cloth masks and common fabric materials against 20–1000 nm size particles. *Annals of occupational hygiene,* 54**,** 789-798.

Santarsiero, A., Ciambelli, P., Donsì, G., Quadrini, F., Briancesco, R., D'Alessandro, D. and Fara, G. 2020a. Face masks. Technical, technological and functional characteristics and hygienic-sanitary aspects related to the use of filtering mask in the community. *Annali di igiene: medicina preventiva e di comunita,* 32**,** 472-520.
Santarsiero, A., Giustini, M., Quadrini, F. and Fara, G. 2020b. Effectiveness of face masks for the population. *Ann Ig*.
Selvaranjan, K., Navaratnam, S., Rajeev, P. and Ravintherakumaran, N. 2021. Environmental challenges induced by extensive use of face masks during COVID-19: A review and potential solutions. *Environmental Challenges***,** 100039.
Veritas 2020. AFNOR SPEC S76-001.
W.H.O 2020. Advice on the use of masks in the context of COVID-19: interim guidance, 5 June 2020. World Health Organisation.
Wilkes, A., Benbough, J., Speight, S. and Harmer, M. 2000. The bacterial and viral filtration performance of breathing system filters. *Anaesthesia,* 55**,** 458-465.
Wilkes, A. R. 2002. Measuring the filtration performance of breathing system filters using sodium chloride particles* apparatus. *Anaesthesia,* 57**,** 162-168.