Nuclear Technology Spinoffs

Indigenously Developed Glass Fiber Media and Development of Various Types of Masks

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EVT Face Mask

NGR Face Mask

ABSTRACT

The COVID-19 pandemic has created an unprecedented demand of respiratory face masks, for personal as well as medical applications, due to the highly contagious nature of the virus. Masks with high filtration efficiency are essential to serve this purpose. WMD, BARC has been working on an indigenous development of filter media for High Efficiency Particulate Air (HEPA) filters for efficient filtration of radioactive aerosols and particulates activities. This technology has now been adopted for the design of a High-Quality Respiratory Face Mask (HQRFM), for common use during the pandemic to serve the society in the time of a health crisis, on an immediate basis. This glass fiber media has minimum retention efficiency of 99.97% for 0.3-micron size particles. Additionally, advanced respirators i.e. Engineered Valveless Transparent Face Mask (EVTFM) (P-100 type), first of its kind in the country, has also been developed using same filtration media. Its key features such as replaceable cartridge, more breathing area and mask transparency etc. make it superior to other masks, and it has potential for use in medical & industrial areas, including nuclear applications. Imported glass fiber media is being used for respirators, such as half face and full-face mask for personal protective equipment, for over four decades in nuclear industry. Utilizing the indigenously developed glass fiber media, nuclear grade half face mask has been designed, for use in nuclear and other industries, at very reasonable cost, thus following Atmanirbhar Bharat ('Self-reliant India'). The paper discusses the work on indigenous development of glass fiber media, development of various types of masks and its technology transfer for ensuring their availability in public domain at an affordable cost in this challenging time.

KEYWORDS: *Face mask, Filter media, Respirator. National Institute for Occupational Safety and Health (NIOSH), High Efficiency Particulate Air (HEPA) filter. Glass fiber medium, Engineered Valveless Transparent Face Mask (EVTFM). High-Quality Respiratory Face Mask (HQRFM). Nuclear Grade Respiratory Face Mask (NGRFM).*

Introduction

Many categories of masks are available in the market depending upon their intended application. These available masks are generally made of synthetic fibres and are being used as medical face masks/respirators. Respirator face mask is categorized by National Institute for Occupational Safety and Health (NIOSH), US. Respirator face masks that collect at least 95% of the challenge aerosol are given a 95 rating. Those that collect at least 99% receive a "99" rating. And those that collect at least 99.97% (essentially 100%) receive a "100" rating. Respirator filters are rated as N, R, or P for their level of protection against oil aerosols. Respirators are rated "N" if they are not resistant to oil, "R" if somewhat resistant to oil and "P" if strongly resistant (oil proof). Thus, there are nine types of particulate respirator filters:

i. N95, N-99, and N-100
ii. R-95, R-99, and R-100
iii. P-95, P-99, and P-100

Filtration mechanism in synthetic media based masks highly depends on electrostatic charge and is vulnerable to charge neutralization during disinfection[1]. Also, filtration mechanism of these masks gets largely affected by various environmental factors. Development of high quality mask was initiated with an aim to utilize indigenously available glass fiber media known for high particulate efficiency for submicron size particles. Glass media mask sterilization can be easily carried out by oven heating (at 60-70°C). Performance of these masks were checked in approved labs at different stages and have reported particulate filtration efficiency, breathing resistance, splash resistance etc. effective enough to fight the present pandemic situation as well as any contagious environment.

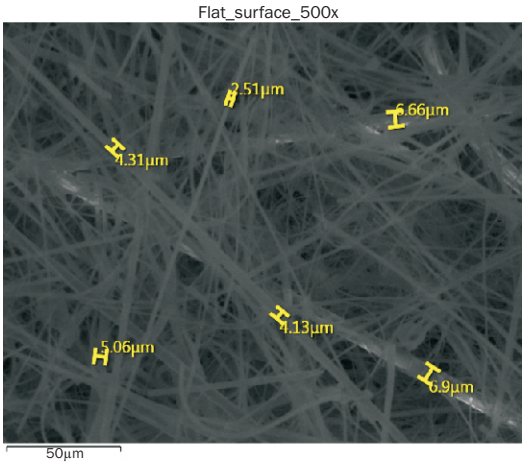

Fig.1: SEM micrographs of developed filter Media.

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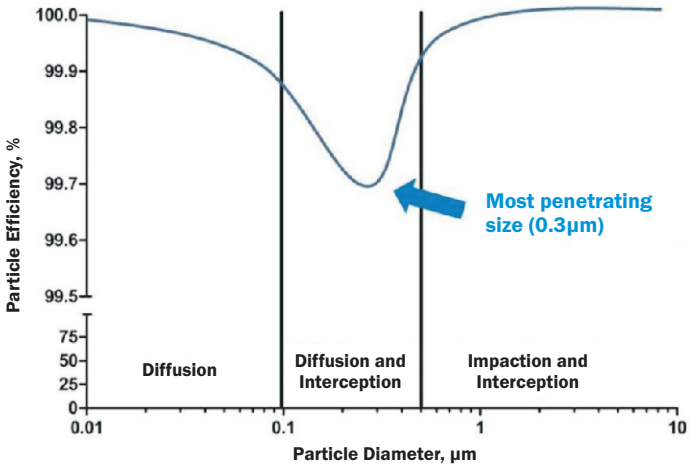

Fig.2: HEPA Filtration Mechanism.

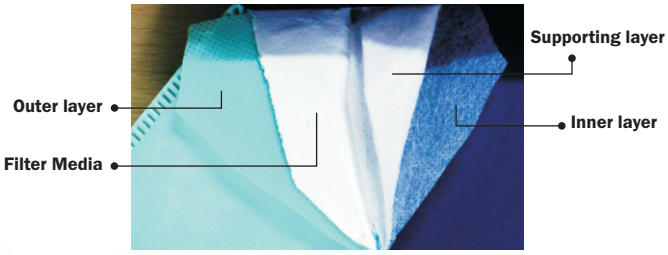

Fig.4: High Quality Respiratory Face Mask.

Fig.5: Technology transfer of HQRFM.

Indigenous Development of HEPA Filter Media

The filter medium used in a HEPA filter is a continuous sheet of paper of around 30 m length and 572 mm width. The thickness of the paper is around 0.4mm. The most commonly used filter medium all over the world is composed of borosilicate type micro glass fibers. Very small quantities of certain binders and additives are also present to impart strength and water repellency. The sub-micron fibers of the filter paper are in random distribution and orientation as shown in Fig.1. The particles in an air stream follow a tortuous path while passing through the paper and get trapped by interception, inertial and diffusion mechanisms. Theoretical as well as practical observations indicate 0.3 micron size particles as the most penetrating through such a fibrous filter medium (Fig.2) and hence the filter media are generally evaluated for removal efficiency against this particle size . In addition to providing the desired filtration properties, the filter medium requires to possess some special physical properties regarding tensile and folding strength, water repellency etc. The annual requirement for HEPA filter media is around 20-30 tonnes for nuclear industry that is presently met by imports.

BARC's effort for indigenous development of micro glass fiber media with the participation of private Indian manufacturers has resulted in development of technology for mill-scale processing of filter medium within the country. The efforts with the firm for establishment of process parameters, composition of additives etc. for nuclear grade is nearly in qualification stage.

The requirement of high efficiency reusable face masks due to the onset of the Covid-19 pandemic, compelled the department to utilize the glass fiber media for production of masks, since the technology for production of glass fiber media is already in a matured stage in India. In this regard, for customization of filtration media for qualification for mask grade, certain parameters were modified to qualify for both national and international standards. This resulted in development of filter media of superior quality in terms of reusability, cost and suitability in all environmental conditions. Mill scale of filter media manufacturing is shown in Fig.3. One limitation with respect to the fragile nature of the media has also been suitably addressed with the development of gauging layer on glass fiber medium, resulting in excellent improvement in its manufacturing quality and for reusability.

Development of Different Types of Respiratory Face Mask

1. High Quality Respiratory Face Mask (HQRFM): While the entire world was under lock down due to Covid 19, Scientists at BARC rose to the occasion and offered solutions to mitigate risk and save precious lives of human kind, by developing very high quality face masks. There has been a huge demand of face masks with efficient filtering of sub-micron sized particles at low cost for both personal as well as medical applications. This specially designed mask has very high particulate filtration efficiency. The main features like comfortable breathing, high filtration efficiency and affordable price make it more attractive. It is an oil resistant and environment friendly mask and is reusable through oven heating. The mask material is a combination of porous synthetic media, glass media and polypropylene (40 GSM), prepared using automated ultrasonic sealing method as illustrated in mask configuration in Fig.4. These reusable masks minimize the waste generation too[2]. Performance of HQRFM has been tested in different BIS/NIOSH approved test set ups for breathing resistance, splash resistance and particulate

Fig.3: Mill scale of filter media manufacturing

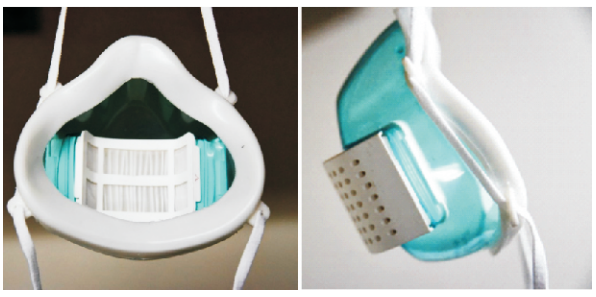

Fig.6: Engineered Valve-less Transparent Face

Fig.7: Technology transfer of EVTFM.

Fig.9: Technology transfer of NGRFM.

Fig.8: Nuclear Grade Respiratory Face Mask.

filtration efficiency etc. and qualifies as better than N95. Advanced version of mask with gauging layer has resulted in enhanced reusable life. So far, more than two lakhs of HQRFM have been produced and have been sent to different departments, hospitals, ministries and also in public domain. This technology is a step towards an Atma-Nirbhar Bharat. Presently, technology for manufacturing of mask has been transferred to three Indian manufacturers under BARC technology transfer scheme.

Engineered valve-less Transparent Face mask (EVTFM): In general, face masks are designed to seal off nose and mouth using a cloth, plastic, or silicone mask, and allow air to only pass through via designated vents or zones. These vents or zones are covered with a special fabric filter that allows clean air to pass through, blocking anywhere from 70% to 99% of particulate matter from entering. In the case of cloth masks, the entire mask acts as a fabric filter, and with something that's non-porous, like plastic or silicone, air valves and smaller filters that can be detached, cleaned, or replaced are provided. That's the basic schematic of a mask and this design encounter roadblocks. Cloth masks are often too flimsy, and while they are easier to breathe through, they don't create a proper seal around face, allowing air to leak through the sides. Plastic and silicone masks, on the other hand, have the reverse problem. They come with an air-tight seal, but those small air-valves make it difficult to breathe through after prolonged usage and are provided with exhalation valves which are not desirable. Opaque nature of these face masks is also a major issue in face recognition during security measures. In order to overcome these limitations, an Engineered Valve-less Transparent Face Mask (EVTFM), a first of its own kind in the country, has been developed using fully indigenous glass fiber (HEPA) filter medium,. It comes with modular construction, ensuring a perfect fit around the face, but instead of opting for tiny air valves and small filters, use of a special curved filter which has an area greater than a typical mask, making it much easier to breathe 99.97% filtered clean air through. Furthermore, due to its increased area it allows both inhalation and exhalation to be filtered, thus avoiding valves for exhalation. Indigenously developed HEPA media is used in a pleated and curved form that covers entire mouth. It constantly filters air while easily trapping all sorts of micro particles into its pleats/folds. The filter qualifies as P100 standard, trapping even the finest particulate matter including viruses, allergens, pollen, and bacteria to deliver 99.97% clean air to nose and mouth. The mask comes with a multi-part design featuring an external plastic cover made from recycled Acrylonitrile Butadiene Styrene (ABS), and an oronasal mask made from Thermoplastic Poly Urethane (TPU) that provides the perfect seal around the face in a way that feels comfortable.

This design is engineered to control the airflow so that the inside of mask never gets hot or humid. The geometry of the filter allows sound waves to propagate and transmit through the mask more readily, further improving usability. The mask's design is entirely modular and can be disassembled to either replace the filter cartridge or to sanitize the rest of the components as shown in Fig.6. These unique key features make it superior to applications in highly contagious environment e.g. medical, industrial & nuclear field[2]. EVTFM developed by BARC has been tested & approved as per international standards set by NIOSH and qualifies as a P100. The technology also has been transferred to an Indian manufacturer and is also being readied to be launched on a commercial platform in the name of "Jivnaank".

2. Nuclear Grade Respiratory Face Mask (NGRFM): Half face and full-face masks with glass fibre media in cartridges form are being used in nuclear applications over the last four decades. These cartridges are presently imported and assembled to form half face masks. Indigenously developed glass fibre filtration (HEPA) technology has been utilized to develop and manufacture full and half face masks as an import substitute in a better configuration making country self-reliant. Since it is indigenous, it is very cost effective. Performance of filter cartridge of NGRFM also has been tested in BIS approved Test set up and the manufacturing technology also has been transferred successfully to an Indian manufacturer as shown in Fig.9.

In-house Development of Media and Mask Test Rig Facility

Indigenous development of media and manufacturing of various types of respiratory face masks demanded in-house test set up for validation of product designed, prior to final certification at Bureau of Indian Standard (BIS) approved lab[3,4]. Procurement of readily available test set up was not feasible due to urgent requirement, pandemic constraints and higher cost. This compelled us to design & manufacture a test set up in-house equivalent to NIOSH standard at a very low cost in a minimum time frame. BARC-developed test rig facility incorporates parameters equivalent to NIOSH approved test set up. It has features for testing of various types of masks as well as filtration media. During the testing of masks, "most

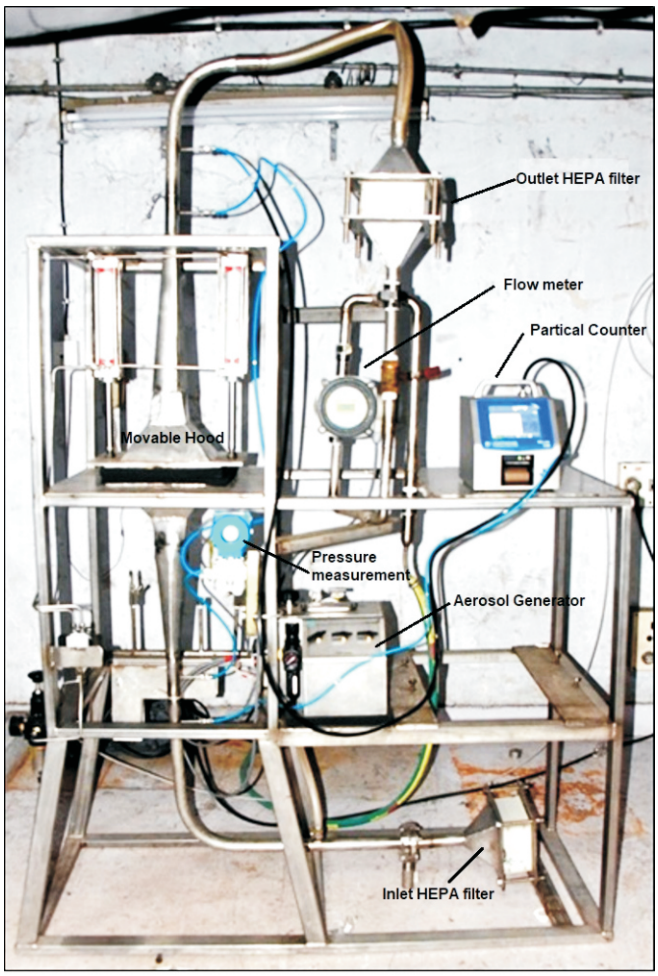

Fig.10: In-house developed Test rig facility.

rigorous" or "worst case" conditions are taken such as test aerosols should include particles at or near the most penetrating particle size range. Air flow should be near the highest level encountered during heavy work, because higher air flow leads to more particles through the filter. The detection method is to measure particles in the most penetrating particle size range with high sensitivity and precision. In the test set up, an Aerosol generator generates aerosols and the concentration of aerosols is controlled using air flow and nebulizer feed pressure etc. Test chamber is operated under vacuum, which is continuously monitored using manometer.

As per international standard, 85 lpm of flow rate is being maintained for Di-Octyl-Pthalate (DOP) based aerosols and to simulate this flow rate as breathing conditions, air is continuously drawn using an air suction pump. Differential pressure is being measured to simulate breathability of masks.

Conclusions

The present requirement of HEPA Filter medium of DAE, about 20-30 tonnes per year, is met by 100% import. Efforts by BARC for indigenization of nuclear grade glass fiber media for HEPA filters are at qualification stage. The development of this filter media is an import substitute, a major step towards Atmanirbhar Bharat. Presently available masks made of synthetic materials (spun bound and melt blown polypropylene fibers) are generally recommended for single use due to main filtration by electrostatic charge. Masks developed using indigenous developed HEPA filter based technology are reusable in nature and this will further minimize the waste generation. Complete indigenous development of filtration technology for mask grade material not only contributes to humanity in times of a global health crisis but also makes our country 'Self Reliant' in letter and spirit. Till date, more than 2 lakh units of High Quality Respiratory Face Masks, 1000 nos. of EVTFM have been produced and deployed in public domain and are being widely appreciated. The technology of HQRFM, EVTFM and NGRFM has also been successfully transferred to an Indian manufacturer for launching on commercial platform.

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