ERGO-DESIGN CONSIDERATIONS ON RESPIRATORY FILTER DESIGN FOR BRICK KILN WORKERS

Design Research Seminar | ID660

Guide: Prof. G. G. Ray

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DECLARATION

The written submission is a part of my report, **'Ergonomic design considerations on respiratory filter design for brick kiln workers'**, is done as Design research seminar project for Post Graduate Program at IDC School of Design, IIT Bombay, under the guidance of Prof. G. G. Ray.

I hereby declare that the thoughts, ideas and words in this document are original and appropriate references are cited wherever due. I understand that the violation of the above can cause disciplinary action by the Institute.

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APPROVAL

The project titled, '**Ergo-design considerations on respiratory filter design for Brick Kiln workers**' by **Pooja B. Kulkarni** is approved in partial fulfillment of the requirements for Master of Design Degree in Industrial Design.

Guide: Prof. G. G. Ray

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A| INTRODUCTION

A.1 BRICK MAKING PROCESS

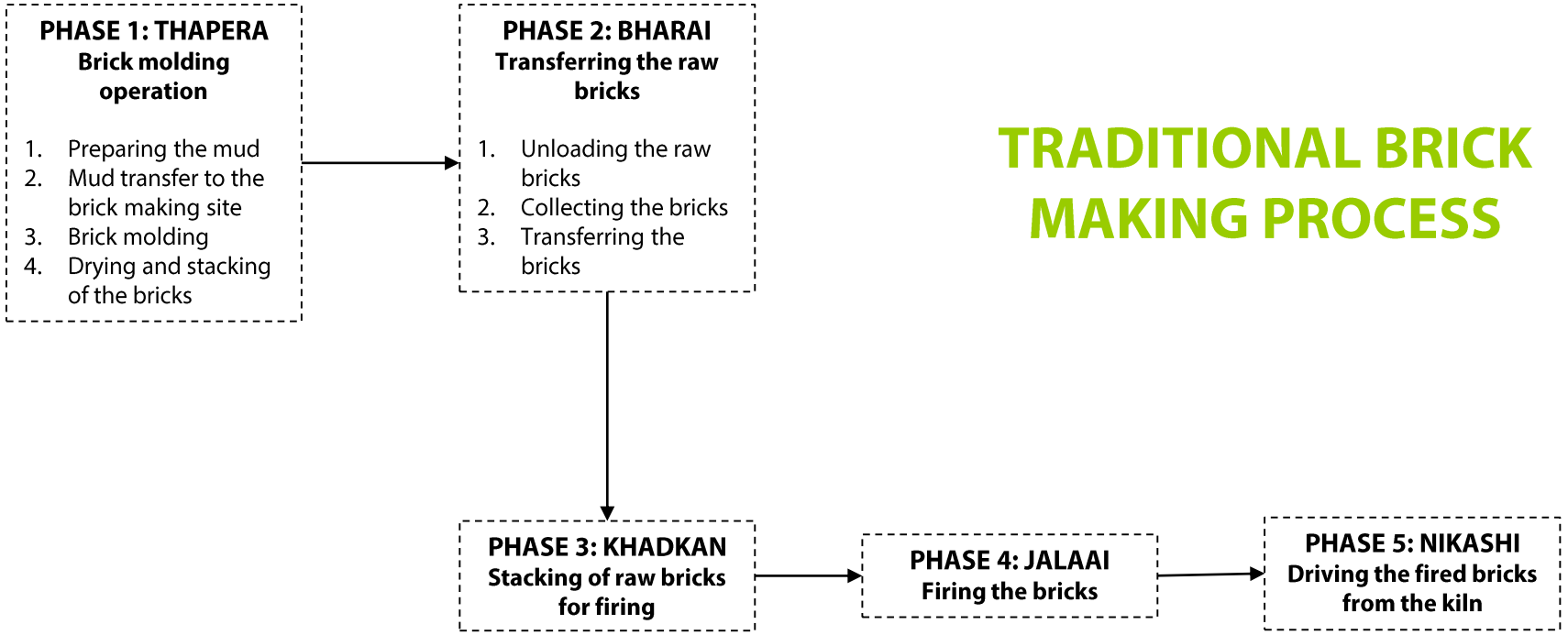
Bricks are a very important raw material in the construction industry. Due to the rapid urbanization the requirement for the bricks is high. India is the second largest producer of bricks (after China), yet most of the tasks are still performed manually.

There is a huge discrepancy in the wages and the working hours for the brick kiln workers. Also the working conditions are wretched. Low wages with hazardous working condition lead to deteriorating health of the workers and lower productivity.

Usually, an entire family is involved in brick production and they get Rs 400-500 for 1,000 bricks. Although the industry provides employment to a large number of people, it violates their rights as the labourers are underpaid and exploited. "The labourers become bonded after they take advance. They are physically tortured by the contractor if they wish to leave their job. Even their payments are stopped, making it hard for an entire family to survive," Sudhir Kumar Katiyar, project coordinator of the Udaipur-based non-profit, Prayas Centre for Labour Research and Action, said at the dialogue.[1]

Fig A.1: Brick manufacturing sites in India
Source: http://www.ecobrick.in/indian_Brick_Sector.aspx

TRADITIONAL BRICK MAKING PROCESS



A.2 ENVIRONMENTAL CONDITIONS

India falls in the tropical region and thus the climate is hot and humid. The major brick making areas are scattered all around the country, with major concentrations in the northern and eastern region of the country.

Brick making is a five step process. The raw materials (sand and clay) are collected and filtered. The mud is then prepared and the bricks are molded. The molded bricks are then dried, stacked and fired. After the firing the bricks are untacked and the kiln is cleaned.

This entire process happens in the same area and workers are constantly subjected to high amount of dust and fumes. Thus apart from the musculoskeletal disorders the brick kiln workers are subjected to lung disorders and thus their overall health is affected.

Fig A.2: Stacking the fired bricks and cleaning the kiln
Source: [2]

Fig A.3: Firing the kiln
Source: [3]

Fig A.4. Mixing of clay.
Source: [8]

A.3 COMPOSITION OF SAND

The brick is made from Silica (sand) that constitutes about 50% of the overall mixture. Alumina is about 20%-30% in the brick mixture. Smaller quantities of Lime, Oxides of Iron and Magnesia are also found in the mixture that contribute in making good quality and durable bricks. [09]

The suspended particle size varies from the 2µm to 90µm. The smaller particles are suspended in air and are more harmful. [04]

A.4 POLLUTANTS

Clay dust contains a mixture of inorganic compounds including free silica, iron oxide, lime, magnesium carbonate, alkalis, calcium carbonate, calcium sulfate, and sodium chloride and varying amounts of organic materials. [02]

The workers are exposed to these pollutants during multiple stages in the brick making process, during the mixing and clay preparation, cleaning the kiln, breaking coal for firing, and the repairable suspended particulate matter (RSPM) during monitoring and regulating the fire.

Epidemiological studies done in different places around the world have found the evidence that increase in rate of bronchitis, asthma, decreased lung function, pharyngitis, cough, eye irritation, fibrosis, emphysema, allergic rhinitis, low birth weight are linked with deteriorating ambient air quality in brick kilns. [02]

Fig A.5: Pollutants that are released into air.
Source: [5]

Fig A.6: Pollutants that are released into air.
Source: [4]

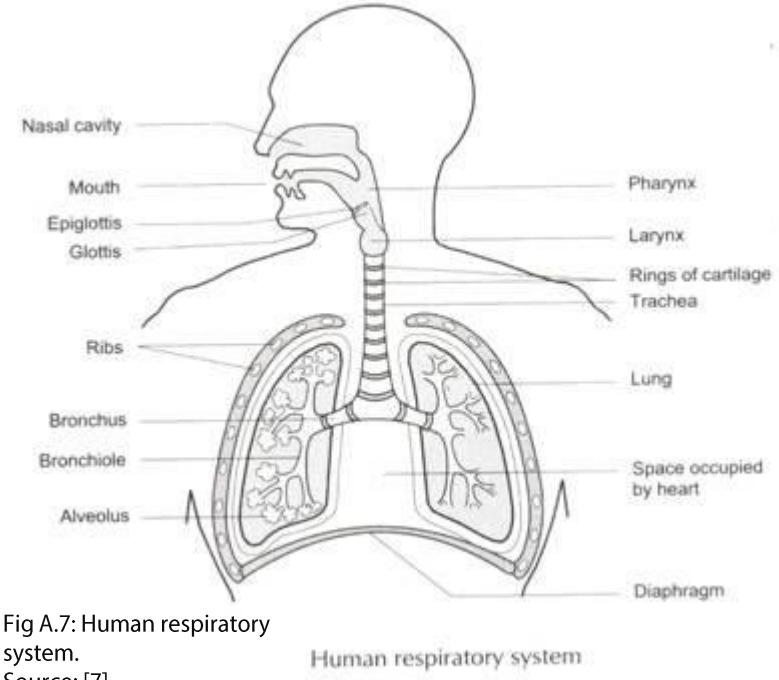


Fig A.7: Human respiratory system.
Source: [7]

A.5 HUMAN RESPIRATORY SYSTEM

The human respiratory system is divided into three regions, each covering several anatomical units, depending on their structure, airflow pattern, function, retention time, and sensitivity to deposited particles. The respiratory system is divided into three main regions,

The head airways region (Extra thoracic or nasopharyngeal region) : The nose, mouth, pharynx and larynx. The inhaled air is warmed and humidified in this region.

The lung airways or tracheobronchial region: Airways from the trachea and the bronchioles. This region is like an inverted tree that branches out.

The Pulmonary or alveolar region: This is where the gas exchange takes place.

The dust particles that are below 10µm are not filtered out by the body and thus get inhaled. These particles settle down in the bronchioles and thus cause a number of diseases.[03]

A.6 DISEASES THAT AFFECT THE RESPIRATORY SYSTEM

There was a study conducted by Shiraz Shaikh, Asaad Ahmed Nafees, Vikash Khetpal, Abid Ali Jamali, Abdul Manan Arain and Akram Yousuf, in the brick kilns in Pakistan to study the respiratory diseases occurring in brick kiln workers. According to this study:

Results of the study show that 22.4% workers had chronic cough while 21.2% reported chronic phlegm.13.8% had two or more attacks of shortness of breath with wheezing. 17.1% workers were suffering from Chronic Bronchitis while 8.2% reported physician diagnosed asthma. Amongst the non-smoking workers 8.9% had Chronic Bronchitis. Multivariate analysis found that workers involved in brick baking were more likely to have Chronic Bronchitis (OR= 3.7, 95% CI 1.1-11.6, p=<0.05) and asthma (OR= 3.9, 95% CI 1.01-15.5, p=<0.05) compared to those involved in carriage and placement work. [04]

Both India and Pakistan fall in the tropical zone and thus face similar climatic conditions. Also, the lifestyle of the people and staple diet is similar. Thus the inferences from the above study can be used as a basis for workers in Indian brick kiln industry.

The brick kiln workers are constantly subjected to constant dust and fumes and thus their health is affected. This reduces their work efficiency and life quality. Thus it is important to reduce this dust inhalation and to try and improve their health.

Fabric masks available in the market currently can be directly used to reduce this problem, but there are other factors that play an important role in their acceptance and use.

- The primary reason to got for a frugal locally sourced mask, is that the mask available currently are costly and thus not affordable to the workers. The maintenance required for the masks is also high. Aesthetically they do not look like a part of their daily attire and thus there is a reluctance to accept them.
- These masks also do not provide overall protection as they do not cover the entire nasal area.
- These masks are not comfortable to wear for a longer duration of work, as the pressure drop is high and thus it gets difficult to breathe. Also due to sweating and physical activity the mask does not fit properly and tends to move.

This project looks into finding low cost, locally sourced fabric materials that can be used to design a nasal mask for brick kiln workers.

B | CONSIDERATIONS

RESPIRATORY MASK CONSIDERATIONS:

Four major considerations need to be addresses while designing a respiratory mask.

1. The dust particle size that can be filtered by the mask.
2. The concentration of particles that are filtered.
3. The pressure drop caused due to the filter barrier.
4. The nasal area should be properly covered so that the air transfer is only through the filter and not through any leak.

C | EXPERIMENT AND TESTING

EXPERIMENT:

Aim: Testing different types of cloth to understand the air filtering quality through it.

Objective: To find out a particular type of cloth material to be used as a respiratory filter for workers in the brick kiln industry.

Method: Identify 2-3 cloth materials which are a traditional attire used by the brick kiln workers and collect samples.

Test the filtration capacity of these samples in a simulated environment with a suction pressure of 35-40 cm H20

Test the collected dust samples for the maximum particle size to determine the efficiency of the cloth samples.

SAMPLE 1
Silk

SAMPLE 2
Polyester

SAMPLE 3
Georgette

SAMPLE 4
Cotton

Fig C. 1: Cloth samples chosen to test for filtration
Source: Self

C.1 TESTING

The first part of the experiment was to collect the sample cloth materials that are used by the brick kiln workers. Used materials were selected, as those will be recycled for the masks. Four samples of cloth, Sample 1: White silk, Sample 2: Red polyester, Sample 3: Maroon georgette and Sample 4: Blue cotton were selected. These are the materials that are frequently used by the females as a part of their daily attire.

A single layer of the cloth was tested for its filtration capacity. A test rig was made using the following components. An air pump used in the fish tank with suction pressure of 70mm Hg was enclosed in an airtight contraption. The top part was replaced with the fabric to be tested. This is the only inlet of air and dust particles, and the cloth fabric acts as the barrier.

An outlet from the pump is let out into a bottle of water. This setup is kept in a dusty environment and run for a duration of one hour for every sample fabric.

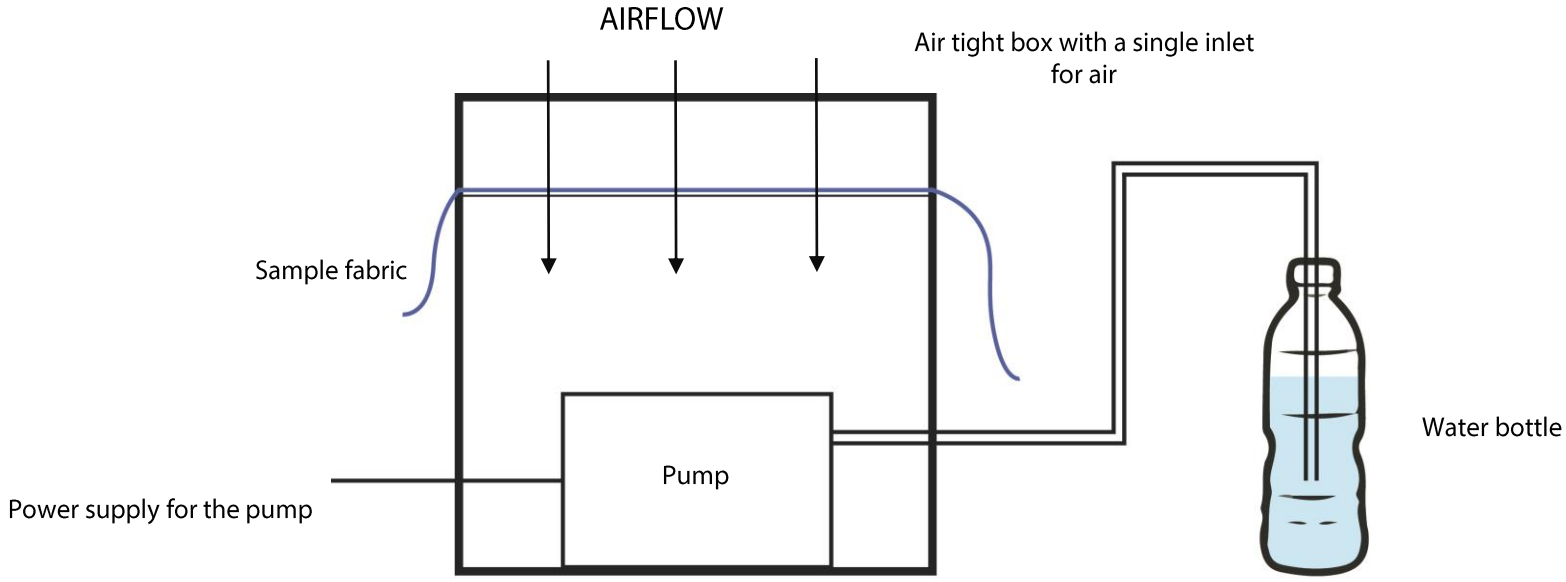
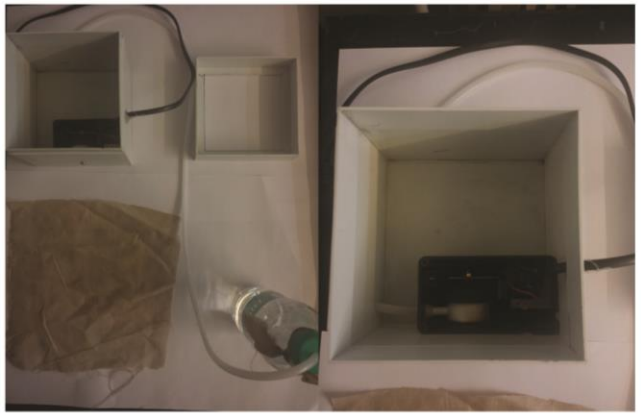


Fig C.2: Schematic diagram of the experiment setup.
Source: Self

Fig C.3: Experiment setup at the site.
Source: Self

For every new cloth sample, the device was cleaned with a wet cloth, dried and then used. The dust samples were collected.



SAMPLE 1
Silk

SAMPLE 2
Polyester

SAMPLE 3
Georgette

SAMPLE 4
Cotton

Fig C.4: Dust sample collection for all four filter cloth samples.
Source: Self

C.2 DUST SAMPLE TESTING

To test the particle size an electron microscope was used. The samples needed to be coated in platinum to make them conductive. After that the samples were viewed under the electron microscope. The largest dimension of the particle were measured and analyzed.

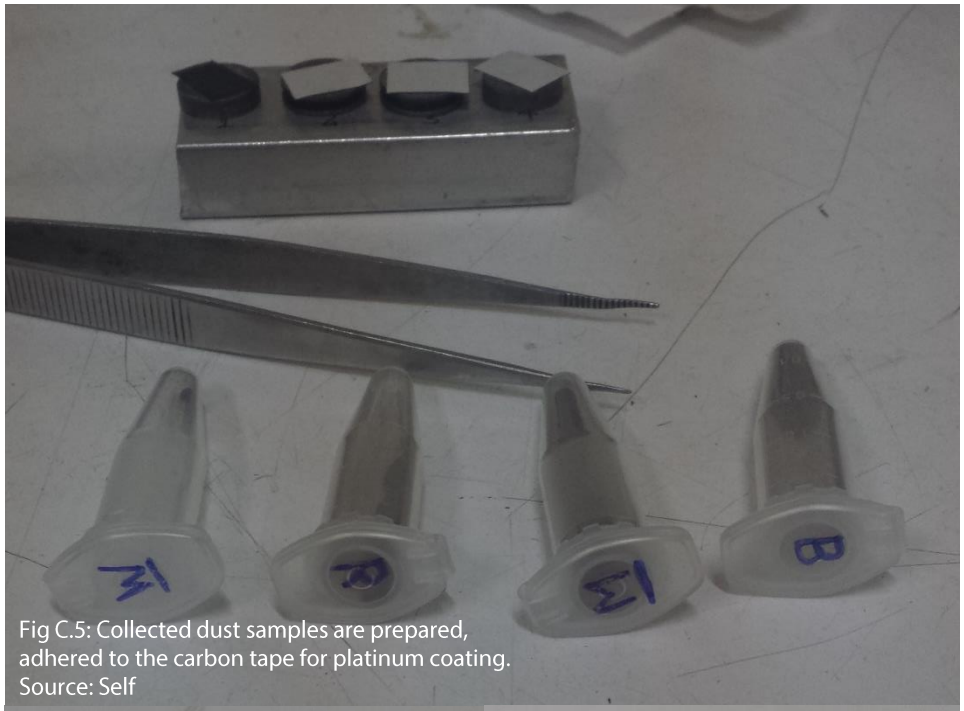


Fig C.5: Collected dust samples are prepared, adhered to the carbon tape for platinum coating.
Source: Self

Fig C.6: Dust Samples before (left) and after(right) platinum coating
Source: Self

SAMPLE 1:SILK

The largest particles in the sample are 318µm, 343µm and 235µm.

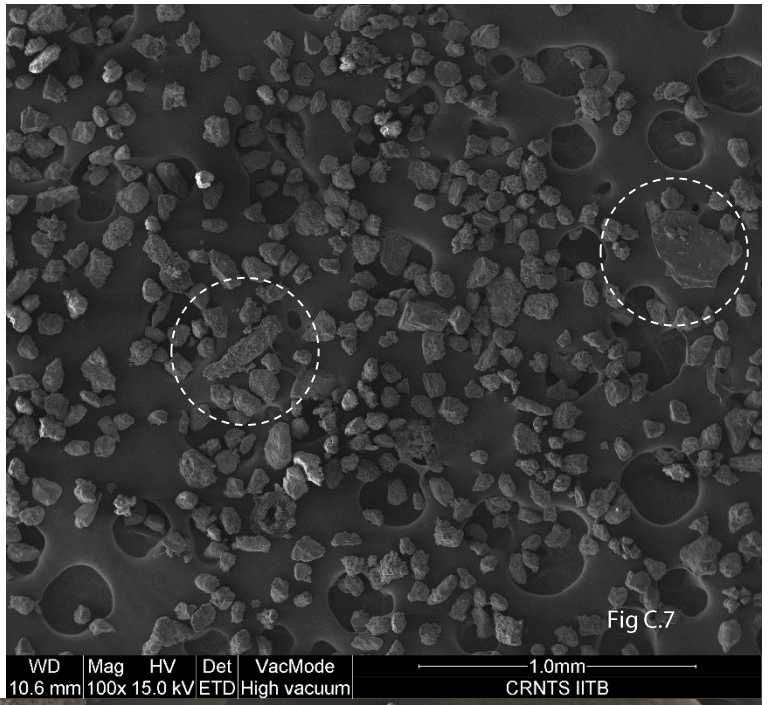
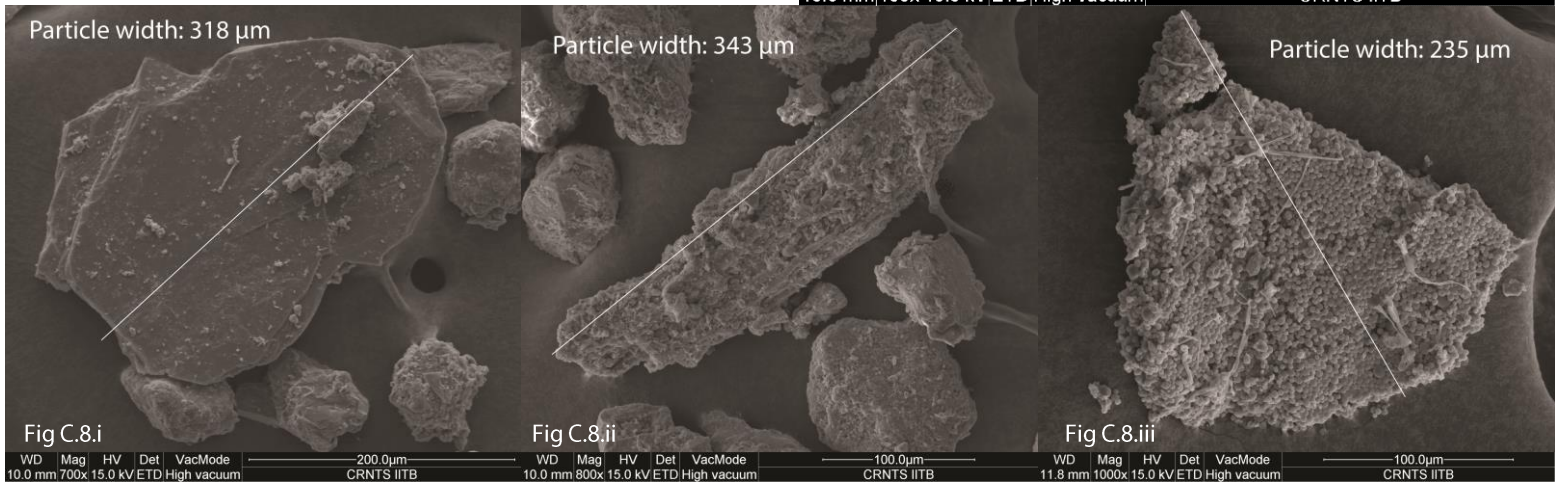


Fig C.7: Dust sample under 100x magnification.

Fig C.8: Largest particles in the sample

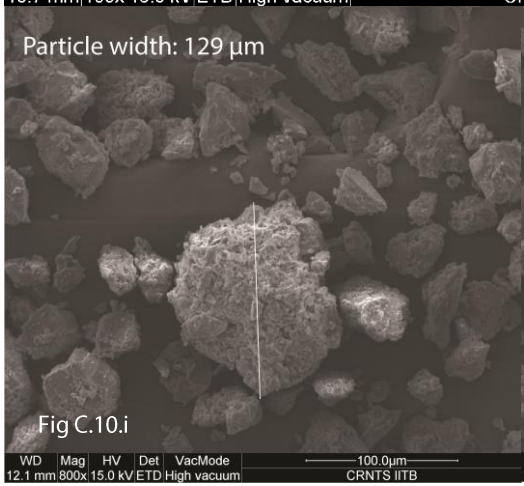


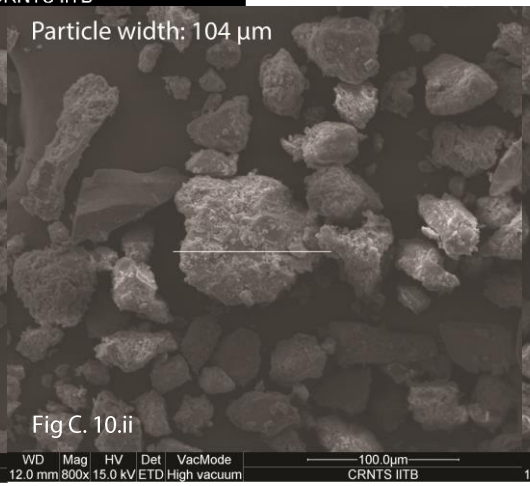
SAMPLE 2: POLYESTER

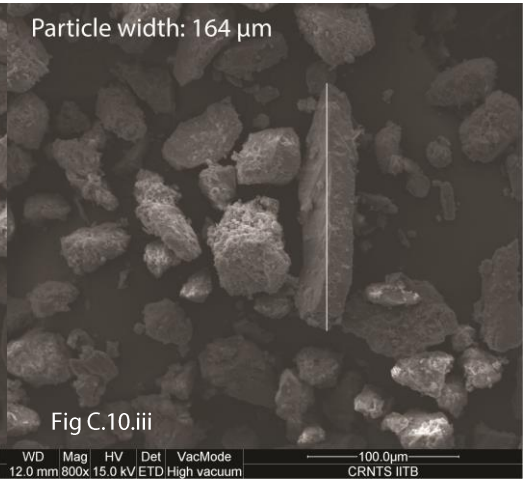
The largest particles in the sample are 129µm, 104µm and 164µm.

Fig C.9: Dust sample under 100x magnification.

Fig C.10: Largest particles in the sample







SAMPLE 3: GEORGETTE

The largest particles in the sample are 256µm, 301µm and 359µm.

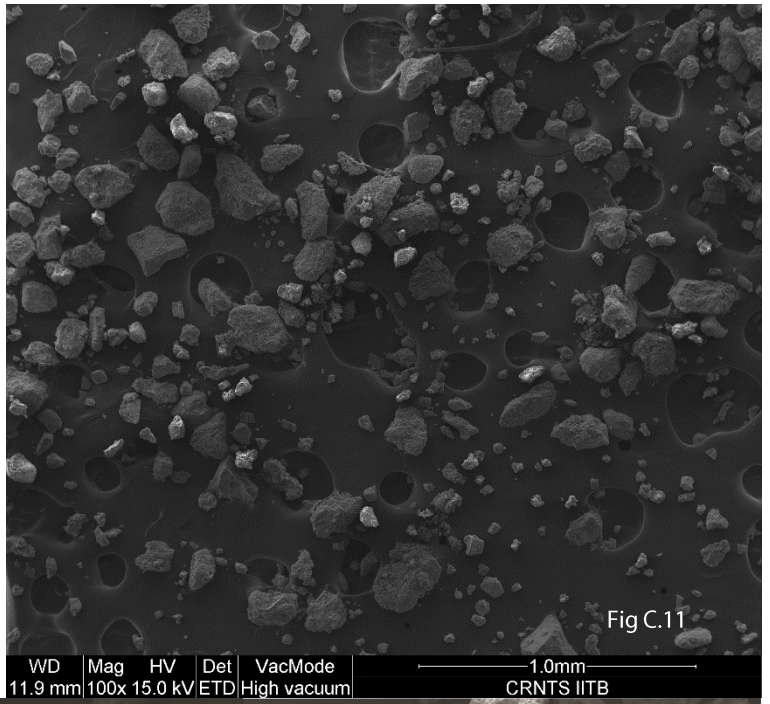


Fig C.11: Dust sample under 100x magnification.

Fig C.12: Largest particles in the sample

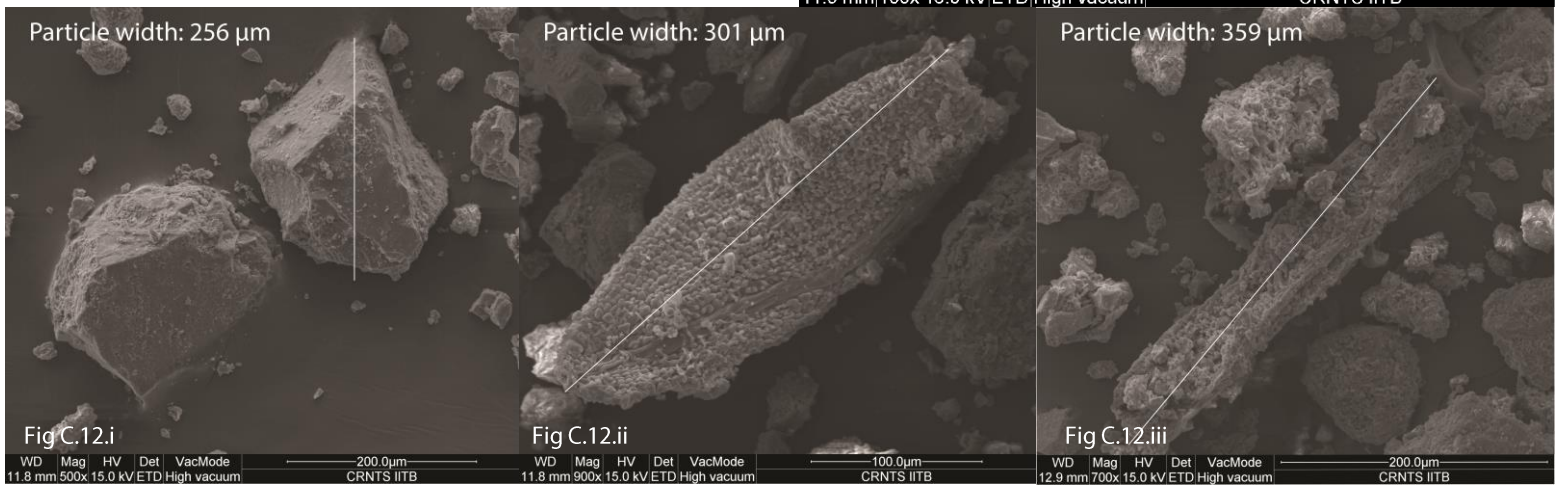


Fig C.13

SAMPLE 4: COTTON

The largest particles in the sample are 360µm, 382µm and 473µm.

Fig C.13: Dust sample under 100x magnification.

Fig C.14: Largest particles in the sample

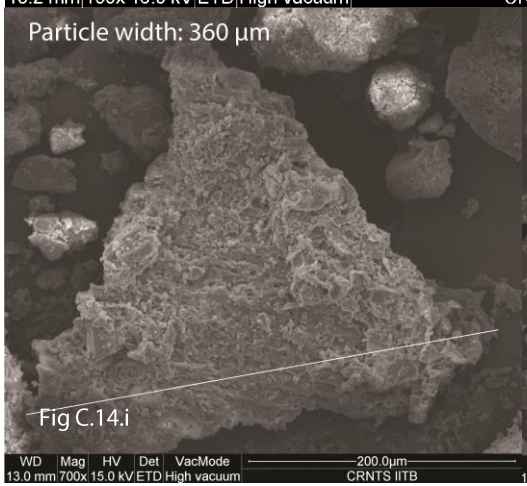


Fig C.14.i

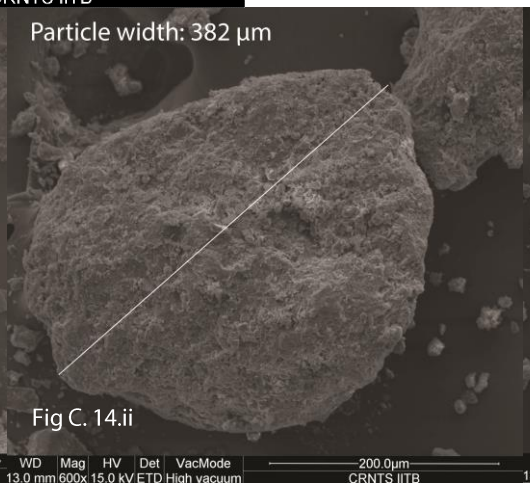


Fig C. 14.ii

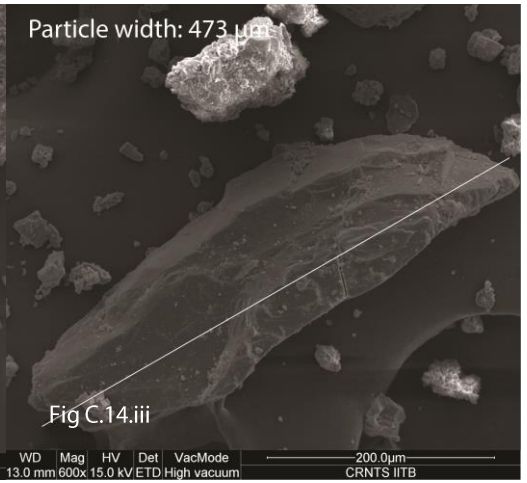


Fig C.14.iii

D | FINDINGS

The following table shows the largest particle size that passes through the filter.

Sample Number	Type	Particle size			
		1	2	3	
1	White silk	318 µm	343 µm	235 µm	
2	Red polyester	129 µm	104 µm	164 µm	BEST
3	Maroon georgette	256 µm	301 µm	359 µm	
4	Blue cotton	360 µm	382 µm	473 µm	WORST

From this table it can be said that Sample 2: Polyester filters out the particles to the best extent as the largest particle in the size is 164µm. Sample 4: Cotton is the worst for filtering dust particles as the largest particle filtered out is 473µm.

Sample 1:Silk and Sample 3: Georgette follow Sample 2, performance wise.

E | CONCLUSION

From the study it can be concluded that polyester is a good material for filtering dust particles, and cotton is the worst. Concentration wise, silk and polyester are good as the amount of dust that penetrates through them is visually less. A lot of factors play an important role in material selection for mask.

The pressure drop is inversely related to the pore size of the filter cloth. Thus natural materials like cotton and silk are more breathable where as synthetic materials are not as breathable. Thus a combined mask with two materials will be able to give a better effect. This needs to be tested to see their efficiency.

Also multiple layers of the same material will also be more effective in filtration. This will also have to be tested.

Lastly this test needs to be carried out in the actual environment, to generate accurate results. Also the materials need to be tested by the users for their comfort level.

IMAGE REFERENCE

Image number	Source	Date and time
01	http://s3.amazonaws.com/medias.photodeck.com/0d4e9d4a-0e2a-11e2-949f-b1f59bcd3642/BAN_081214_411_xw_large.jpg	28/03/2017 | 6.42 PM
02	http://www.photoburst.net/photo_section/photos/marked1200/brick-kiln-workers-diamond-harbour-india-canon-eos-5d-mark-iii-ef-24-70mm-lopamudra-talukdar.jpg	28/03/2017 | 6.42 PM
03	http://www.crispinhughes.co.uk/blog/wp-content/uploads/2015/05/MG_9302.jpg	28/03/2017 | 6.42 PM
04	http://tribune-intl.com/wp-content/uploads/2015/06/env-peshawar.jpg	30/03/2017 | 5.23 PM
05	https://c.tribune.com.pk/2012/02/341824-Brickkilnsphotofile-1330194729-388-640x480.jpg	30/03/2017 | 5.23 PM
06	http://www.ecobrick.in/images/map-2(brickmaking%20in%20india).jpg	30/03/2017 | 5.23 PM
07	http://cdn.biologydiscussion.com/wp-content/uploads/2014/01/clip_image0025.jpg	06/06/2017 | 11.25 AM
08	https://cdn.nplus1.ru/images/2017/04/06/767b8b5860af39415fb330ebf1d4f6f9.jpg	06/06/2017 | 11.26 AM

REFERENCE

Number	Source	Date and time
01	http://s3.amazonaws.com/medias.photodeck.com/0d4e9d4a-0e2a-11e2-949f-b1f59bcd3642/BAN_081214_411_xw_large.jpg	28/03/2017 | 6.46 PM
02	BRICK KILN INDUSTRY AND WORKERS' CHRONIC RESPIRATORY HEALTH PROBLEMS IN MIT GHAMR DISTRICT, DAKAHLIA GOVERNORATE by Sheta S and El Laithy N	02/06/2017 | 12.38 PM
03	Aerosol Technology: Properties, Behavior and Measurement of Airborne Particles, Second Edition by William C. Hinds	
04	Respiratory symptoms and illnesses among brick kiln workers: a cross sectional study from rural districts of Pakistan by Shiraz Shaikh, Asaad Ahmed Nafees, Vikash Khetpal, Abid Ali Jamali, Abdul Manan Arain and Akram Yousuf	
05	http://www.sos-arsenic.net/english/environment/toxic-fumes.html	16/01/2017 | 4.00PM
06	https://businessimpactenvironment.wordpress.com/2011/10/03/environmental-pollution-from-brick-making-operations-and-their-effect-on-workers/	16/01/2017 | 4.00PM
07	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3507845/	16/01/2017 | 4.01PM
08	http://www.webmd.com/lung/lung-diseases-overview?page=2	16/01/2017 | 4.03PM
09	http://www.civileblog.com/bricks/	06/06/2017 | 6.49 PM