DESIGN AND MANUFACTURING OF PERSONAL PROTECTIVE EQUIPMENT (PPE) IN NEPAL

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DESIGN AND MANUFACTURING OF PERSONAL PROTECTIVE EQUIPMENT (PPE) IN NEPAL

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A REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE CREDIT REQUIREMENT IN PANDEMIC FOR MEEG 213

PREPARED FOR

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MAY 24, 2020

TO: SURENDRA SUJAKHU, PhD
FROM: SARVESH PANDEY (21162)
DATE: MAY 23, 2020
SUBJECT: DESIGN AND MANUFACTURING OF (PPE) IN NEPAL.

Here is the report on design and manufacturing of Personal Protective Equipment in Nepal that you authorized on May 10, 2020.

PPE is equipment that will protect the user against health or safety risks at work. It can include items such as safety helmets, gloves, eye protection, high-visibility clothing, safety footwear and masks. The equipment is personal because it is used individually and not shared with others. Most of them are thrown away after being used one time. They are protective because the equipment works as a barrier between the body and the germs.

This report manifests the possibilities of forming PPE sets in Nepal along with the raw materials needed to manufacture it and the design procedure that are in practice all over the world to protect the medical personnel from COVID-19 Corona virus and other influenzas as well.

Thank you for allowing me the opportunity to participate in this worthwhile study. And I will be very happy to discuss its finding with you.

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CHAPTER 1 INTRODUCTION

1.1 Background

PPE was thought to be originated during World War I as a mean to prevent the soldiers from chemical intoxications. The use of chemicals shifted the mode of war and to overcome it, PPE was originated. The use of respirators allowed the troops to escape the effects of harmful toxins and gas. Similarly, the use of masks and gloves assisted the scientists and researchers to work in a safe environment. In the middle ages blacksmiths used to wear Apron and hand gears to prevent them from being burned and to stop the equipment from falling on their body [1]. The modern industry has drastically evolved since then, with greater focus on protective work wear for a wide range of trade industries. PPE now extends to clothing, footwear, goggles and other garments that are all designed to protect an individual from injury. Early PPE like body armor, boots and gloves focused on protecting the wearer's body from physical injury. The doctors of sixteenth-century of Europe also wore protective uniforms which consisted of a full-length gown, helmet, glass eye coverings, gloves and boots to prevent contamination when dealing with affected victims. These were made of thick material which was then covered in wax to make it water-proof. A mask with a beak-like structure which was filled with pleasant-smelling flowers, herbs and spices to prevent the spread of bad smells which spread disease through the air[2].

Fig 1: Complete PPE set

(RSS, 2020)

1.1.1 COMPONENTS OF PPE

PPE or personal protective equipment is defined by the Occupational Safety and Health Administration (OSHA) as "specialized clothing or equipment worn by an employee for protection against infectious materials" [3]. It is very important to select the correct PPE. Just as important, the PPE must be working correctly every time we use it, either alone or in combination with other PPE. The components of PPE are listed below with short description:

a) Face shield
b) Mask
   I. Triple layer medical mask
   II. N-95 respiratory mask
c) Gloves
d) Gowns
e) Shoe covers
f) Head covers
g) Goggles

A brief introduction of each component is given below:

a) Face shield:

A face shield is an item of Personal Protective equipment that aims to protect the wearer's entire face from chemical splashes or potentially infectious materials. A face shield provides splatter protection to facial skin, eyes, nose, and mouth. Visors can be made up of plastics such as **polycarbonate**, **propionate**, **acetate**, **polyvinyl chloride**, and **polyethylene terephthalate glycol** (also known as PETG). The plastic is often given anti-glare, anti-fog, anti-static, or other coatings. The attached suspension systems can include elastic straps, Velcro, headbands, glasses-type temple bars, pin-lock, or ratchet systems [4].

Fig 2: Protective face shield

b) Mask:

Masks are designed to keep operating rooms sterile, preventing germs from the mouth and nose of a wearer from contaminating a patient during surgery. Although masks have seen a rise in popularity among consumers during outbreaks such as the coronavirus, surgical masks are not designed to filter out viruses, which are smaller than germs. Masks are made using specialized machinery, and then sterilized. **Nonwoven polypropylene** and textile material is fed from bobbins into machinery that cuts and ultrasonically welds it together [5]. Surgical masks typically have one layer of textile material surrounded by other layers of nonwoven material on both sides, making for 3-4 layers total depending on the mask. The machine attaches other parts like ear loops or metal strips before the masks are sterilized and packaged.

Fig 3: Triple layer face mask

Fig 4: N-95 respiratory mask

c) Gloves:

Gloves are disposable/non-disposable PPE set used during medical examinations and procedures to help prevent cross-contamination between caregivers and patients. Medical gloves are made of different polymers including **latex, nitrile rubber, polyvinyl chloride** and **neoprene**; they come unpowdered or powdered with corn starch to lubricate the gloves, making them easier to put on the hand [5].

Fig 5: Various types of gloves

d) Gowns:

Gowns are medical safety suits worn by professionals as Personal Protective Equipment (PPE) in order to provide a barrier between patient and professional. They may also be used to help prevent the gown wearer from transferring microorganisms that could harm patients. They are classified as disposable and reusable isolation gowns.

- Disposable (single-use) isolation gowns are designed to be discarded after a single use and are typically constructed of nonwoven materials alone or in combination with materials that offer increased protection from liquid penetration, such as plastic films [6]. The basic raw materials used for disposable isolation gowns are various forms of synthetic fibers (e.g. **polypropylene, polyester, polyethylene**). Fabrics can be engineered to achieve desired properties by using particular fiber types, bonding processes, and fabric finishes (chemical or physical treatments).

- Reusable (multi-use) gowns are laundered after each use. Reusable isolation gowns are typically made of **100% cotton, 100% polyester, or polyester/cotton** blends. These fabrics are tightly woven plain weave fabrics that are chemically finished and may be pressed through rollers to enhance the liquid barrier properties. Reusable gowns generally can be used for 50 or more washing and drying cycles [6].

Fig 6: Disposable isolation gown

Fig 7: Reusable gown

e) Shoe covers:

Shoe cover provides a barrier against possible exposure to airborne organism or contact with a contaminated environment. It reduces the spread of contaminations and helps to maintain a cleaner room environment [7].

Fig 8: Shoe cover

f) Head covers:

Head covers protect the hair and scalp from possible contamination when sprays or airborne exposure is anticipated [8].

Fig 9: Disposable head covers

g) Goggles:

Goggles are forms of protective eyewear that usually protects or encloses the area around the eye in order to prevent particulates, droplets or chemicals from striking the eyes. They are designed to provide eye protection from splashed or sprayed body fluids [9].

Fig 10: Safety goggles

1.2 Objective

1. To adopt a system approach for design and manufacture PPE set in Nepal.
2. To establish the measures to access and compare the effectiveness of PPE.

1.3 Scope

1. It can be used by medical personnel to treat COVID-19 patients safely.
2. It can be utilized to treat patients from several pandemics that are to come in future.

CHAPTER 2 DISCUSSIONS

2.1 Purpose

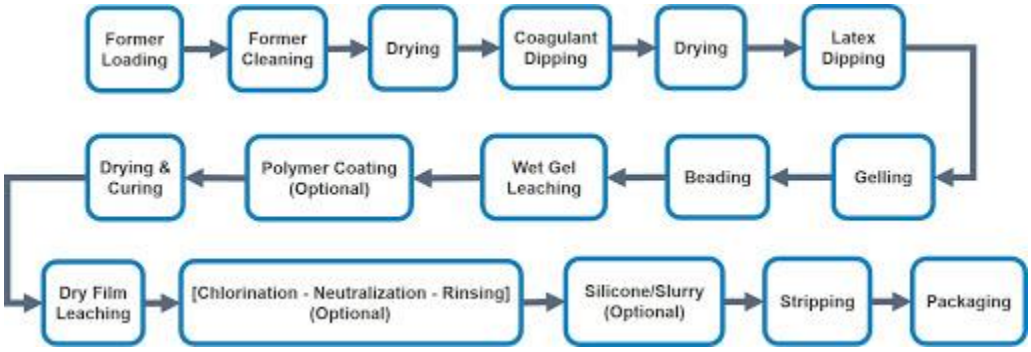
Personal protective equipment is special equipment you wear to create a barrier between you and germs. This barrier reduces the chance of touching, being exposed to, and spreading germs. Personal protective equipment (PPE) helps prevent the spread of germs in the hospital. This can protect people and health care workers from infections. All hospital staff, patients, and visitors should use PPE when there will be contact with blood or other bodily fluids. Due to pandemic spread all over the world there has been shortage of PPE set all over the world. Personal Protective Equipment (PPE) is most important in preventing transmission of the COVID-19 Corona virus not only in treatment centers but also various activities, e.g. cleaning, waste management and safe burials, and community care related to the outbreak. The purpose of this report is to overcome the lack of PPE set in Nepal by designing and manufacturing it within Nepal.

2.2 Design of PPE

In present context, lack of PPE has become a burning problem for healthcare workers all over the world. Especially developing countries like Nepal are facing this problem because of lack of infrastructures and raw materials. Also, lack of skilled man power is a major cause of it. The number of COVID-19cases are continuing to grow in the world, Health care facilities worldwide is contending with an increasing crush of patient, and growing more and more desperate for the tools they need to protect themselves from catching and spreading the virus that causes infections.

2.3 Gloves designing process:

Gloves designing are quite a complex job in the sense, it is a lengthy process. The gloves have to pass through a number of steps, namely former cleaning, coagulant dipping, drying, latex dipping, leaching, beading, vulcanizing, post leaching, slurry dipping, stripping, tumbling, and quality control [10].



2.3.1 Decision matrix for material selection of gloves

The decision matrix for various materials that can be used in making gloves is shown below:

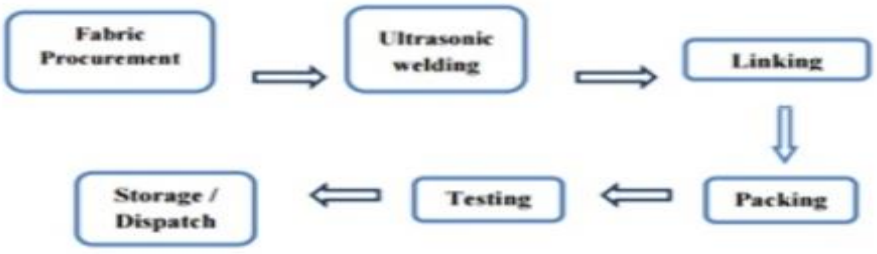
Material	Chemical Resistance	Comfort	Tensile Strength	Puncture Resistance	Cost	Durability	score
Latex	2	4	2	2	3	3	16
Nitrile	5	3	5	5	4	5	27
Vinyl	1	2	3	1	5	3	15

Table 1: Decision matrix for material selection of medical gloves

From the above table it can be seen that the chemical resistance, Tensile strength, Puncture resistance, Durability is very good for Nitrile gloves. The cost of latex glove is low as compared to the other two. From the table it can be concluded that Nitrile gloves is best among all and it is generally preferred by health personnel.

2.4 Mask designing process:

Surgical face masks are made with non-woven fabric, which has better bacteria filtration and air permeability while remaining less slippery than woven cloth. The material most commonly used to make them is polypropylene, either 20 or 25 grams per square meter (gsm) in density. Masks can also be made of polystyrene, polycarbonate, polyethylene, or polyester.20 gsm mask material is made in a spun bond process, which involves extruding the melted plastic onto a conveyor. The material is extruded in a web, in which strands bond with each other as they cool. 25 gsm fabric is made through melt blown technology, which is a similar process where plastic is extruded through a die with hundreds of small nozzles and blown by hot air to become tiny fibers, again cooling and binding on a conveyor. These fibers are less than a micron in diameter [5].



2.4.1Decision matrix for material selection of mask

Materials	Impact Resistance	Durability	Chemical Resistance	Density	Cost	Score
Polyethylene	4	4	4.5	5	4	21.5
Polystyrene	2	3.5	3	4	3	15.5
Polycarbonate	3	3	2	3	2	13

Table 2: Decision matrix for material selection of mask

From the above table, the score of polyethylene is highest among all. Polyethylene has good chemical resistivity and high density. Similarly, it is more durable and long lasting. So, for efficient mask production, Polyethylene is used most.

2.5 Gown designing process:

A surgical gown is a class 2 medical textile used to reduce the transfer of bacteria from the skin of surgical staff to air of operating room as well as protect the surgical staff from contact with bodily fluids. Gowns are most often constructed from fibers such as polypropylene and polyester, by using a nonwoven technique. These fibers are relatively too cheap to make but produce a high quality product [6]. Typically, a gown uses the nonwoven technique known as SMS which stands for spun bond, melt blown, spun bond. In some cases the SMS process can include more than one melt blown layer between the outer spun bond layers.

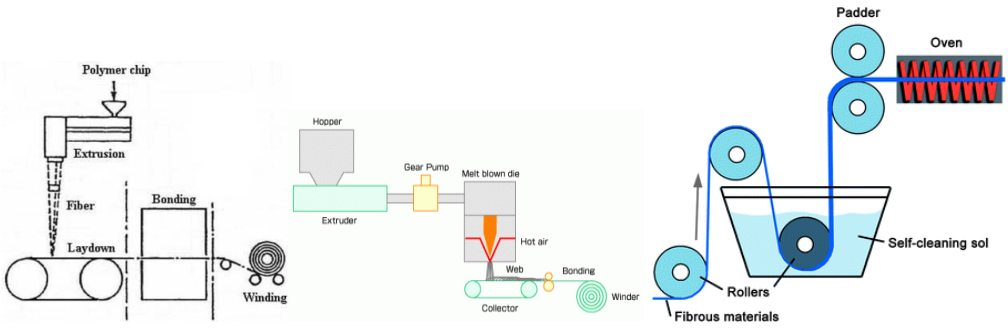


Fig a: spun bonding process fig b: melt blowing process fig c: pad-dry-cure process

2.5.1 Decision matrix for material selection of gowns

materials	elongations	Density	Melting point	Chemical resistance	strength	score
Polypropylene	4	2	3	4	2	15
polyester	2	4	4	2	4	16

Table 3: Decision matrix for material selection for gowns

From the above table, the score of polyester is highest among all. It has good elongation, and good chemical resistance. It seems to be the winner for making medical gowns.

2.6 Face shield designing process:

Two methods are used to manufacture face shields: They are extrusion and injection molding. Face shields cut from extrusion sheets provide better impact resistance than injection molded face shields because extrusion sheets are made of high molecular weight plastic pellets while injection molding must use lower molecular weight plastic pellets, which provide better melt flowing property needed by injection molding [4].

2.6.1 Decision matrix for material selection of face shield

Materials	Impact Resistance	Optical Quality	Material Cost	Chemical Resistance	Elongation	Score
Polycarbonate	4	5	3	4	4	20
Cellular acetate	3	3	5	5	3	19
PETG	5	4	3	3	2	16

Table 4: Decision matrix for material selection for face shield

From the above table, it can be seen that the score of Polycarbonate is higher than cellular acetate and PETG. The winner is Polycarbonate for making face shield. It is also cost effective

2.7 Goggles designing process:

Goggles and safety glasses are typically created using an injection molding process that injects a polymer material into a metal mold that has been fabricated to reproduce the desired shape of the lenses and frames. The exact steps used to make goggles and safety glasses will depend on the particular type of product being fabricated [9]. The steps for fabricating medical goggles are:

a) Mold creation
b) Injection molding
c) Surface treatment
d) Inspection and final production
e) Packaging

2.7.1 Decision matrix for material selection of goggles

Materials	Hypo allergic	Light Weight	Strength	Flexible	Corrosion Resistance	Score
Cellulose acetate	3	4	2	2	3	14
Cellulose propionate	5	5	3	3	4	20
Nylon	3	3	5	4	3.5	18.5

Table 5: Decision matrix for material selection of goggles

Beside them, Polycarbonate is also used which is also a good material. But, while talking about effective material, Cellulose Propionate is used widely to make goggles for medical persons.

2.8 Shoe covers designing process:

Shoe covers are designed by various textile companies. Polypropylene or plastic is used to make disposable shoe covers that prevent the germs and bacteria from entering into the operation room [7].

2.8.1 Decision matrix for material selection of shoe cover

Materials	Cleanliness	Cost	Durability	Anti-skid	Score
Polypropylene	2	4	3	3	12
Plastic	4	2	4	4	14
Polyethylene	2	3	3.5	4	12.5

Table 6: Decision matrix for material selection of shoe cover

Generally, plastic is used as raw material for manufacturing shoe covers because of its various good properties. It gives good cleanliness and it is cheap as well. Also, it is durable and has good anti-skid property.

2.9 Head covers designing process:

Head covers are designed with the same materials that are used to design Shoe covers. It includes materials like Polypropylene, Plastics and Polyethylene [8].

2.9.1 Decision matrix for material selection of Head covers

Materials	Cleanliness	Cost	Durability	Anti-skid	Score
Polypropylene	2	4	3	3	12
Plastic	4	2	4	4	14
Polyethylene	2	3	3.5	4	12.5

Table 7: Decision matrix for material selection of head cover

CHAPTER 3 CONCLUSIONS

The above mentioned materials in the decision matrix are the best suitable materials to manufacture PPE kits in Nepal. Using these raw materials, PPE kit can be manufactured in Nepal and we can learn about PPE designing from this report. The designed PPE set can help the medical personnel to be safe from COVID 19 corona virus and other influenzas as well.

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