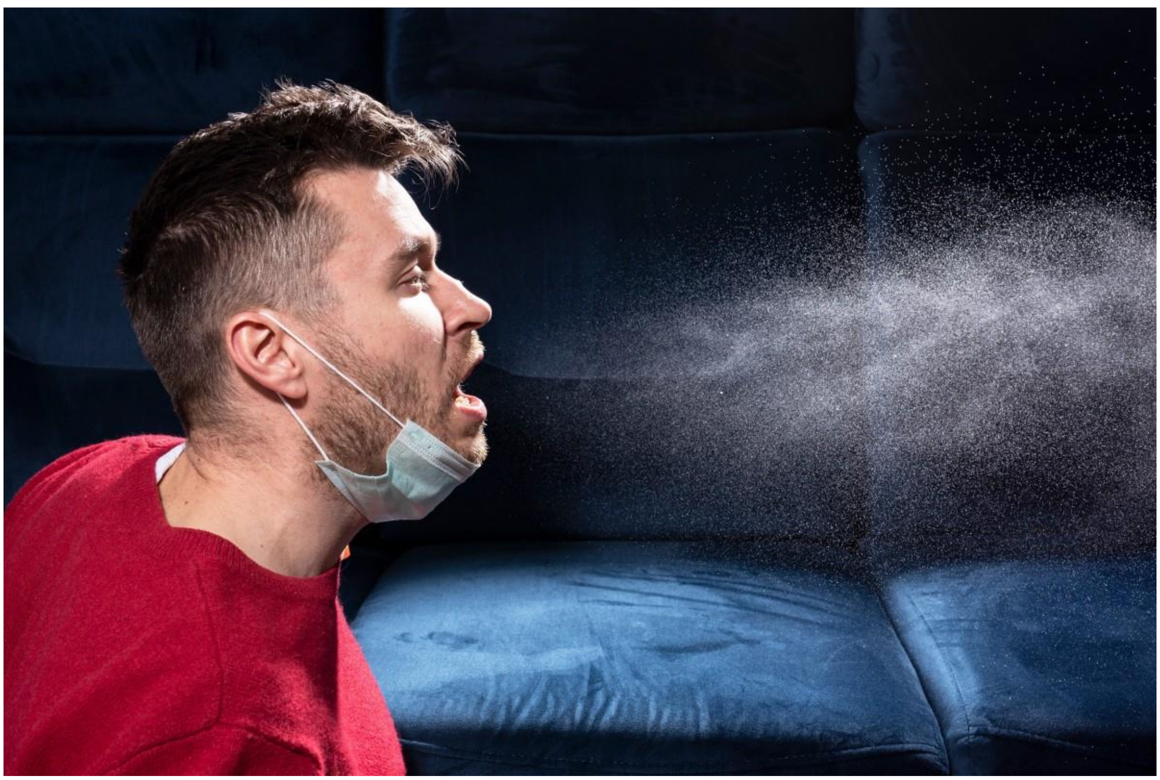
BLOW ME AWAY !

An investigation into hygienic cough



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Year 8
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2020

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Abstract

In the coronavirus pandemic of today, it is more important than ever to have appropriate PPE for, not only healthcare workers, but for the general public as well. When designing facemasks, it is true that an ineffective facemask is worse than no face covering at all. To prevent further waves of outbreak and deaths all over the world, we need to slow the spread. There are many difficulties associated with testing facemasks on the general public, not least of which is human error in their usage. Testing is hard to achieve, as participants would need to cough on demand. When we are told to cough, rather than cough naturally, we often exaggerate the motion, leading to an unrealistic cough. To combat this problem, a model was designed to allow for quick, hygienic and standardised testing of facemasks.

The model was tested in a trial-and-error manner. After each test, the parts of the experiment that met the criteria were kept, and those that didn't were changed. There were three criteria for the success of the model: accuracy, reproducibility, and safety.

Accuracy was the similarity to a human cough. During each experiment, a preliminary test was completed to determine the likelihood of success of the model. A hand was held in front of the mouth to determine whether there was an aerosol spray or not. If the model passed this test, the model would be tested using Cobalt Chloride paper.

Reproducibility dealt with the ease with which an experiment could be reproduced by having as many of the variables controlled as was possible.

Safety dealt with both the safety of the operator and the durability of the apparatus. The final model, designed after many trials, is safe for the operator and can be used many times over without breaking or varying its function.

The modelled cough was found to be similar to a human cough. Only one human cough variable was tested, that of an older male, so more data on coughs would be needed to make a final statement on the effectiveness of the model. The model was found to be an effective and accurate representation for one variable of human cough.

Introduction

In the coronavirus pandemic of today, facemasks have been at the centre of many heated debates. With the coronavirus spreading as quickly as it does, it is essential that we find ways to stop the spread.
I live in Burnie, where we had a coronavirus outbreak in late March. The North West Regional Hospital was the centre of the outbreak, and the area was sent into hard lockdown for a few weeks. Despite having about a fifth of Tasmania's population, we had over two thirds of the state's cases during the outbreak. I am eager to stop this from happening again, and one of the ways to prevent this is to not only keep the coronavirus out, but to contain it once it gets in. Tasmania has not had a coronavirus case for a while, but as demonstrated in Victoria, the virus is a force to be reckoned with.

I started off wanting to research facemask efficiency but stopped when I realised the hygiene issues associated with testing. One of the main functions of facemasks is they must be useable by everyone. This requires widespread testing, which gives rise to issues of hygiene, such as what I would do with the contaminated facemasks afterwards. These concerns lead me to the idea of using a remote set up to stimulate a cough.

When I looked on the internet for ideas, I found nothing. It seemed that the primary ways of testing facemasks were either on real people, or using a facemask stretched over a pump. These methods either were not possible due to hygiene concerns, or not accurate as they failed to consider the different face shapes and fits of facemasks. These errors led me to the idea of creating an accurate, hygienic setup to measure facemask efficiency. I wanted to create a reliable cough stimulator for facemask testing, that both allowed for fit over a face and was hygienic, so it could be tested quickly and easily.

I will build and test a cough stimulator of my own design, comparing it to a real cough in terms of droplet spread. I will continue to make modifications to my design throughout the testing process, in order to find the most accurate stimulator.

To prepare for this experiment I have researched studies from around the world to observe the methods used. In some papers, (Fischer, et al., 2020), the purpose of the experiment was similar to my own, with the purpose being to find a way to measure droplet spread. However, the methods suggested required expensive equipment. I have attempted to come up with an alternate way of measuring droplet spread, using Cobalt Chloride. Cobalt Chloride is a repeating crystalline structure of Cobalt and Chloride atoms, which is blue in colour. When water is absorbed, the chemical structure rearranges itself around the water molecules, making Cobalt Chloride Dihydrate, which is purple in colour.
When more water is absorbed into the Cobalt Chloride Dihydrate, the structure rearranges itself further, with six water molecules for every Cobalt Chloride. The Cobalt Chloride hexahydrate which is formed is pink in colour. The colour change is almost instantaneous, making it an extremely useful tool for detecting moisture. Cobalt Chloride is sensitive enough to pick up moisture in air, making it useful for detecting the spread of small droplets of water.

3.0 Hypothesis & Variables

Hypothesis

If a mannequin is set up to model the spread of aerosol droplets, then modifications will be possible to arrive at a close approximation of the likely distance of aerosol projection from a human cough.

Variables

The independent variable: The design
Dependent variable: Aerosol spread
Controlled variables: Mannequin used, height from which the mannequin is held

4.0 Materials & Method

Materials

Romak Angle Bracket 63mm X 63mm X 16mm ZP
Zenith 10G X 40mm Gold Passivated countersunk screws
Abey 30 X 1mm X 30m galvanised punched strapping.
"Little Anne" hospital Mannequin
Kite surfing pump with metal shaft
Kitesurfing pump with plastic shaft
Kitesurfing hose with end of … diameter
Three meters of kitesurfing rope
Kitesurfing quick release mechanism
Two pulleys, to fit the rope.
10kg weight (provided by a container filled with water)
Electric drills
Drill bits to suit the screws used
Set square
Cobalt Chloride solution ($CoCl_2$)
Three pieces of paper.

Method

1st Model

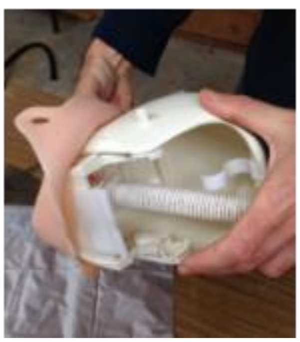
1. The skin covering the belly of the mannequin was removed.

2. The lung of the mannequin was detached from the piping then the bag was removed.

3.
4. The ribs of the mannequin were removed.
5. The skin of the mannequin's face was removed.

6. The piping was removed from the mouth.
7. The valve was removed from the piping.

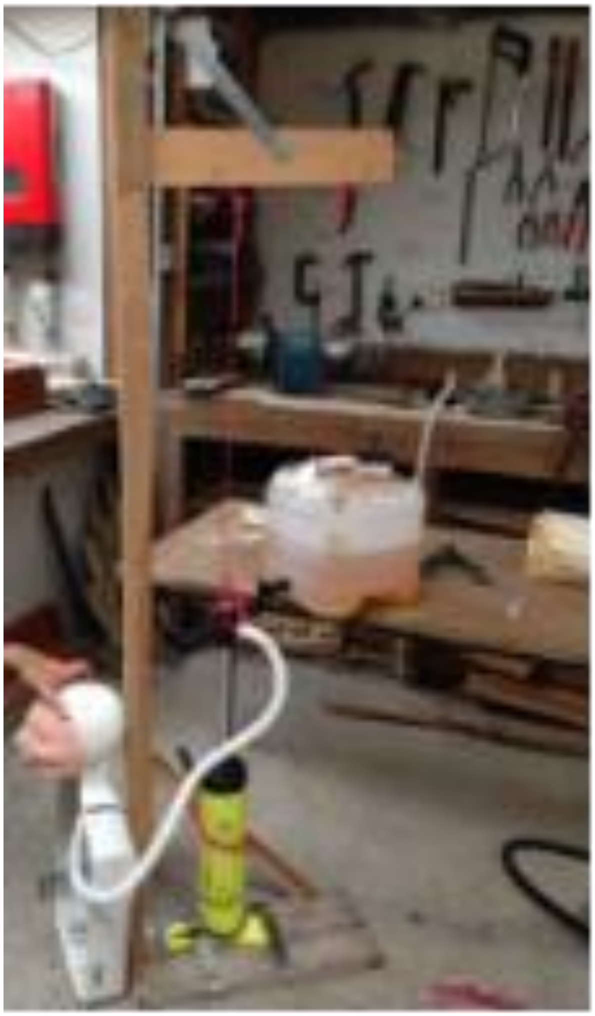
8. All materials apart from the facial skin, plastic head and body were put aside.
9. The kite hose was connected to the mouth joint behind the skin.



10. The fly wire was put into the mouth of the mannequin.

11. The main apparatus was arranged as shown in the diagram. Measurements are as follows (all in mm)
    - Base length: 520
    - Base width: 210
    - Base height: 25
    - Total height: 1950
    - Length of metal: 420
    - Crossbar width: 90

Distance to fall: 330
Smallest diagonal: 370
Medium diagonal: 620
Vertical post width: 30
Vertical post length: 50
The pump used was plastic shafted.



12. The carton was filled with 10 kg of water.
13. The kite hose was connected to the pump.
14. A loop of non-stretch rope was tied over the carton.
15. The carton was hung from the crossbeam using the loop of rope.
16. The model was tested

2nd Model:

The apparatus from the 1st model was changed as follows:

1. The plastic-shafted pump was replaced by a metal shafted version
2. The model was tested

3rd Model

The apparatus from the 2nd model was changed as follows:

1. The fly wire in the mannequin's mouth was changed to a loosely woven fabric.

2. The model was tested

4th model:

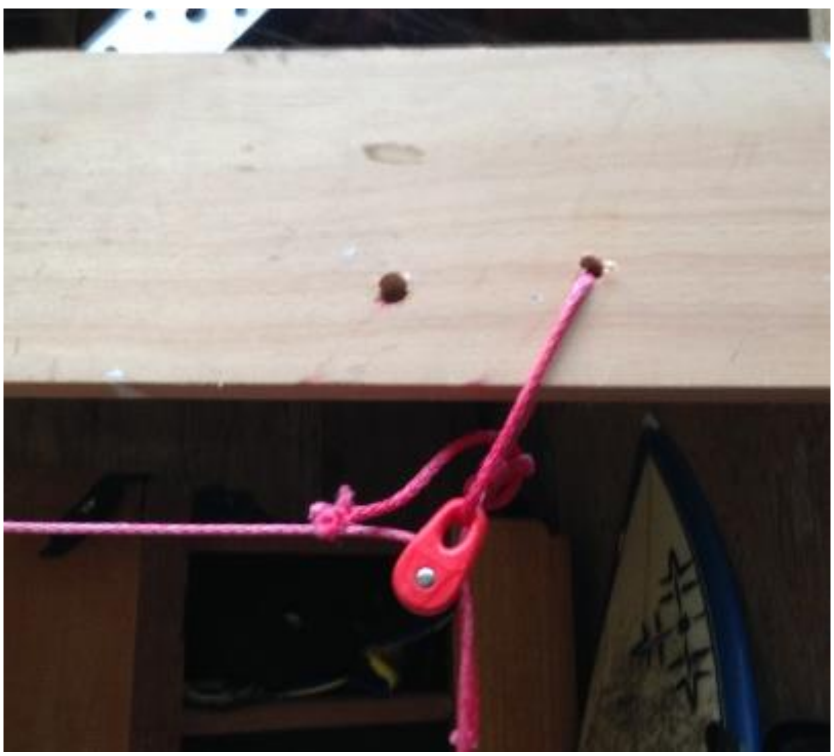
The apparatus from the 3rd model was changed as follows:

1. Both the fly wire and the fabric were placed in the mannequin's mouth
2. The model was tested

5th model:

The apparatus from the 4th model was changed as follows:

1. The fly wire was removed from the mouth of the mannequin
2. The hole that the first pulley was attached to was moved from 18cm to 13 cm away from the crossbar

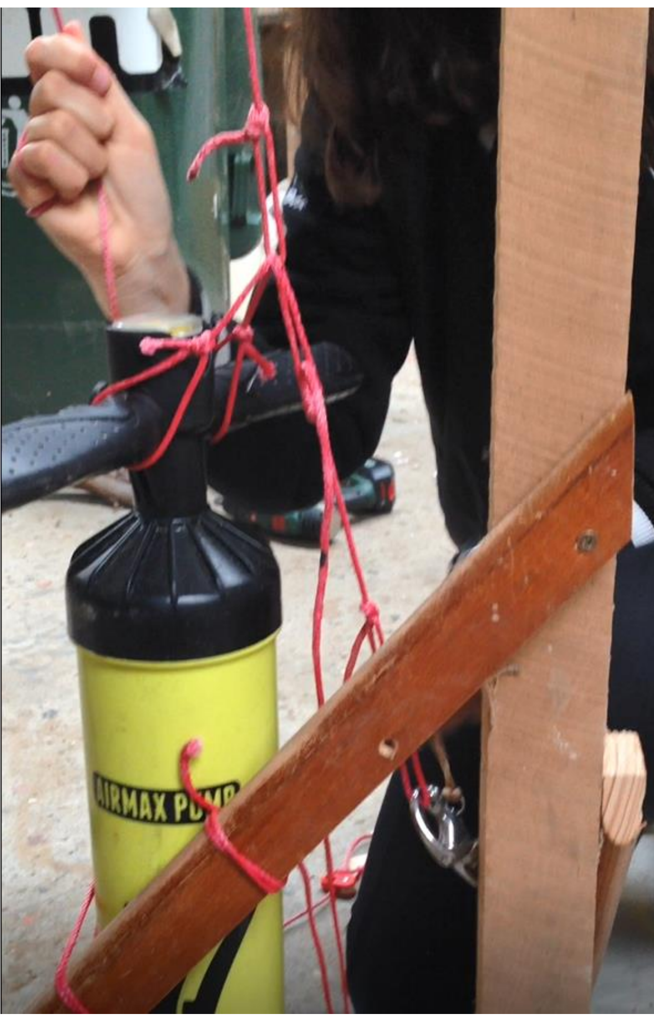


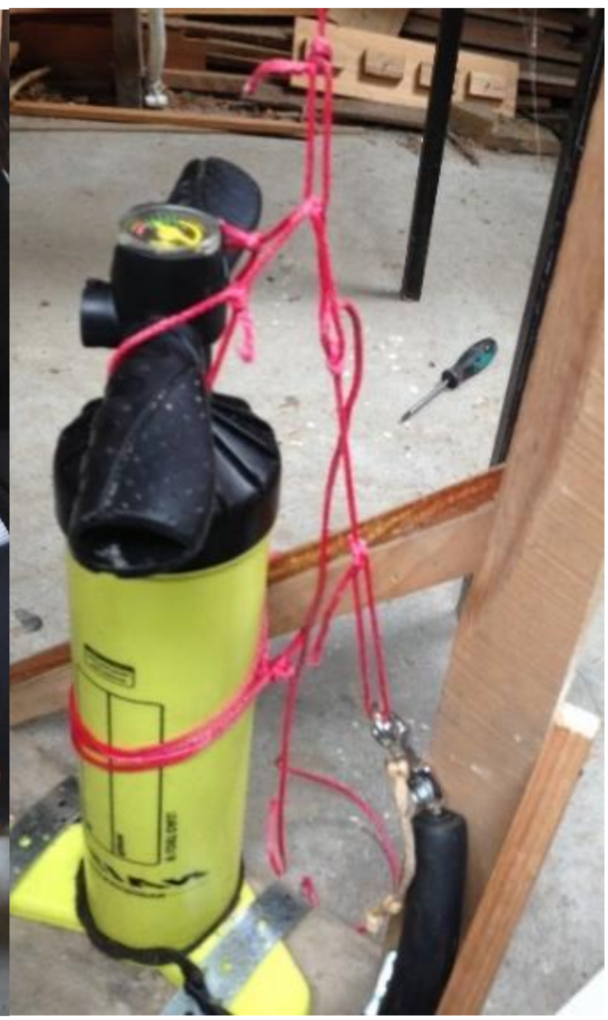
3. The model was tested

6th model:

The apparatus from the 5th model was changed as follows:

1. The quick release mechanism from the kitesurfing gear was attached to the vertical post
2. A loop of rope was attached to the quick release mechanism as to allow the loop to escape when the cord is pulled.
3. The end of the loop was attached to the end of the pulley rope as shown in the diagram
4. A piece of rope was tied to the base board and then to the knot where the rope from the pump handle joins the quick release mechanism. When set up correctly, this rope would prevent the pump from being fully extended at any one time and ensuring the pump would remain undamaged.
5. The model was tested

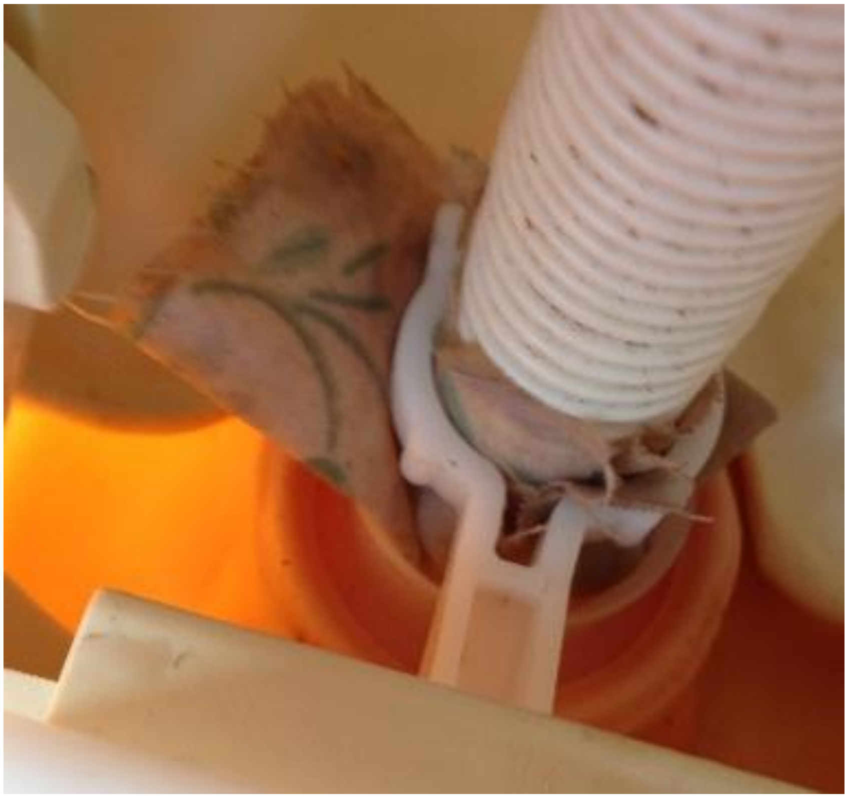




7th model

The apparatus from the 6th model was changed as follows:

1. The skin was taken off the head of the mannequin
2. The hose was taken out of the mannequin's mouth
3. The fabric was taken out of the mannequin's mouth
4. The fabric was stretched over the hose and secured with a rubber band

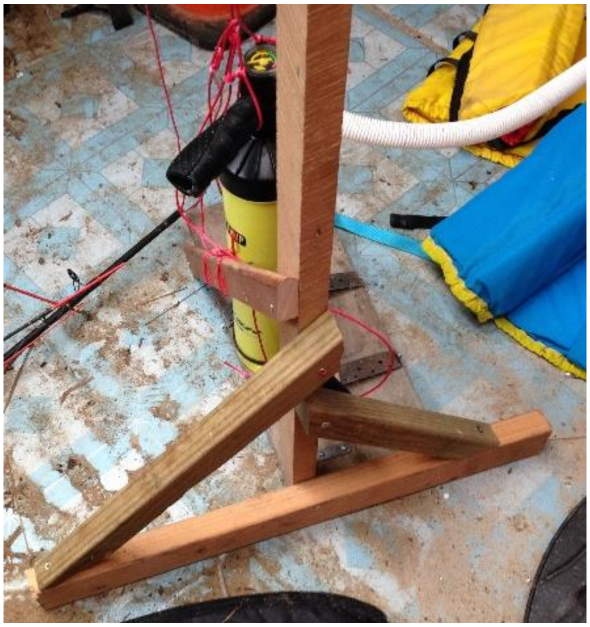


5. The hose was reconnected to the mouth valve
6. The model was tested

8th model:

The apparatus from the 7th model was changed as follows:

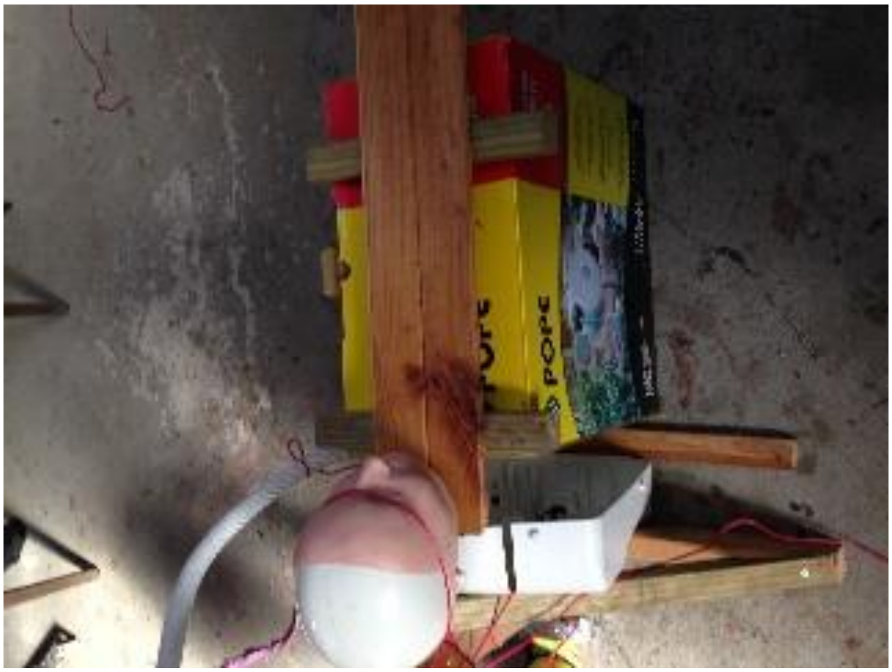
1. The crossbeam was remade as shown in the photograph.
   The measurements of the small and medium diagonals were kept constant. The large diagonal was 680mm long.



2. The model was tested

To test the model:

1. A plank was laid on a box as to be 50mm down from the bottom of the mannequin's mouth.



2. The Cobalt Chloride paper was placed on the plank of the mannequin
3. The trigger was released, making the mannequin cough.
4. Steps 2-4 were repeated 3 times, with the paper dried in between.
5. The paper was dried out.
6. A human cough was recorded at the same height as the mannequin.
7. Steps 6-7 were repeated 3 times, with different pieces of paper for each.
8. The pieces of paper from a human and the modelled cough were compared.

Results

The results for these trials take the form of measuring the distance travelled by droplets released from the simulated cough.

Furthest distance travelled in each trial

	Modelled cough	Human cough
Trial 1	28.6	28.2
Trial 2	29.7	28.3
Trial 3	31.4	28.5
Mean	29.9	28.3

Images of total droplet spread from model:

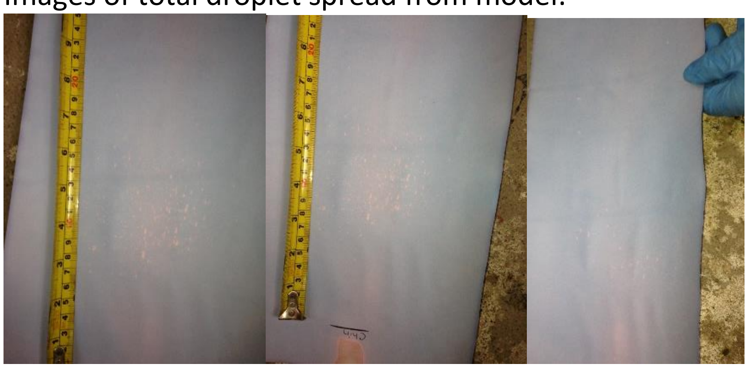
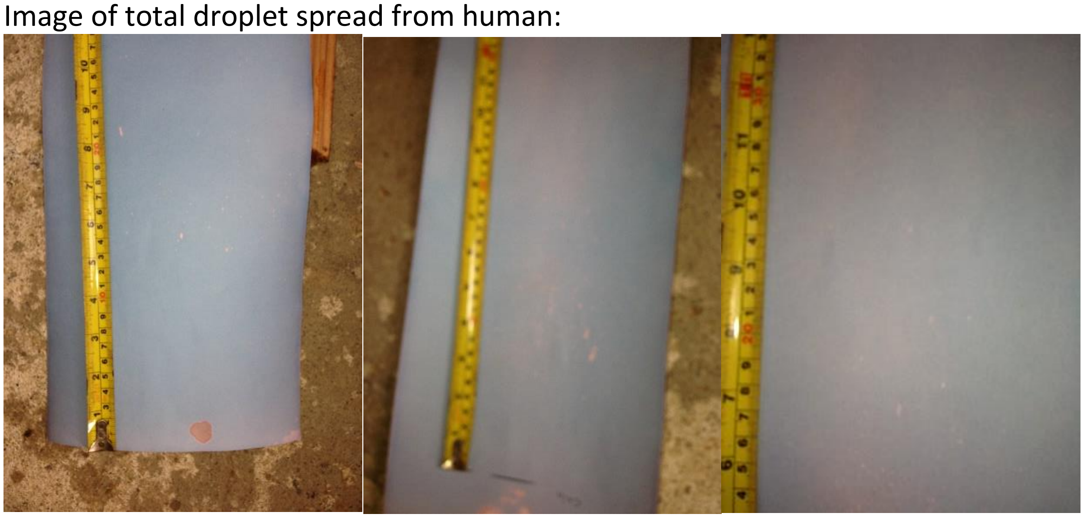
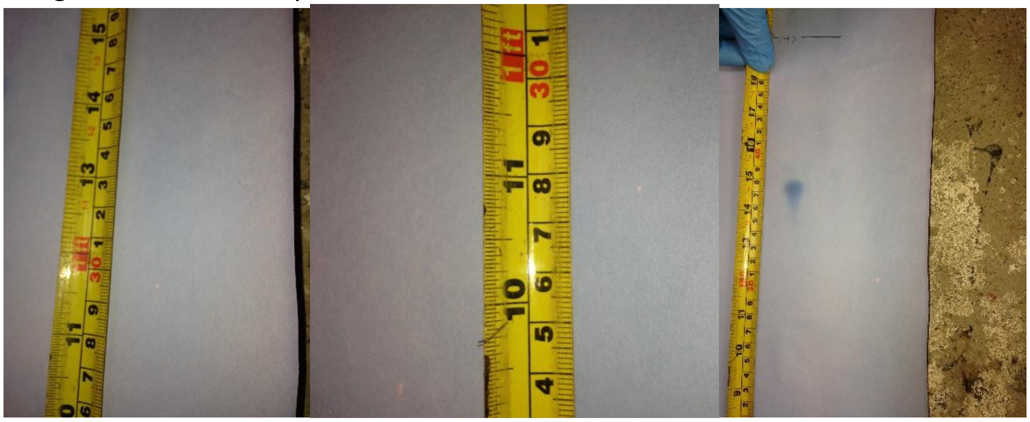


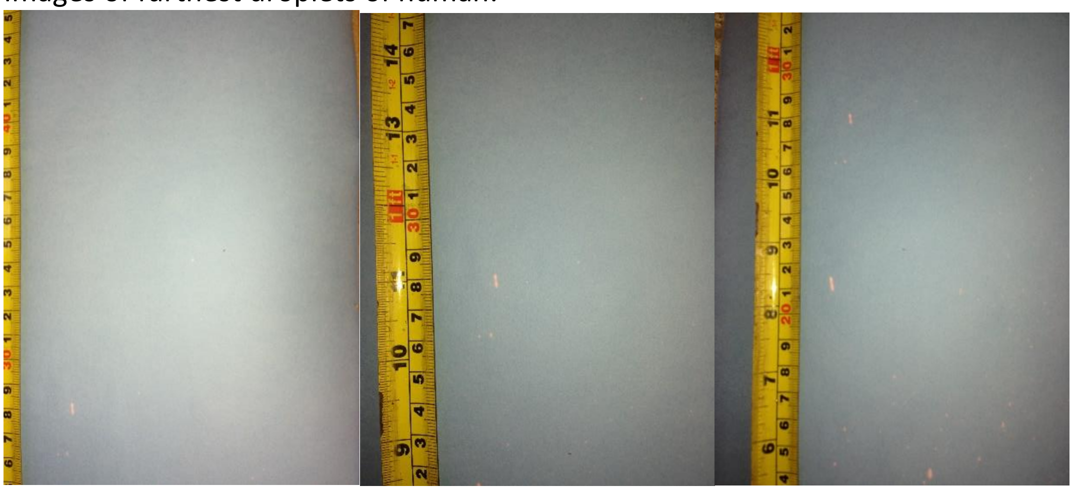
Image of total droplet spread from human:



Images of furthest droplets of model:



Images of furthest droplets of human:



6.0 Discussion

The models were set up and tested in a trial and error manner. Small adjustments were made over a series of trials, to arrive at a simulator that best mimicked a human cough.

The first model worked in that it provided a definite ‘breath’ of air onto a hand in front of the mannequin’s mouth. The challenge was getting it to make an aerosol spray.
The problem with this model was the lack of droplets. The first solution to this was to change the pump. The plastic shafted pump that was in use at the time had a higher amount of friction between the shaft and the casing, contributing to the low velocity of the cough. The metal shafted pump had less friction and it was hoped that it would allow for a spray to be produced.

In the second model, the plastic-shafted pump was replaced with a metal-shafted one. The plastic pump had more friction, slowing down the speed of the air blowing through the fly wire. The theory was that this slow air flow prevented any droplets from being picked up into a spray. The metal-shafted pump allowed for some spray; however, it was still barely noticeable. This led to the need for a third model.

The third model was producing a definite breath of air, this time combined with a small aerosol spray. To try and increase the efficiency of the model and produce a larger spray, fabric was used in the mouth instead of flywire. The fabric produced a larger spray of droplets, but more was still preferable. This led to the fourth model.

The fourth model had both the fly wire and fabric in use. This was expected to produce an even larger spray, as if the spray from each were combined. However, it instead produced a larger spray of droplets, but with almost no force behind them. The increased amount of resistance had decreased the airflow. The model had an unnaturally humid breath, with almost no velocity. The fly wire was removed from the mouth to prevent this from happening again. The low velocity of the breath was seen as a poor simulation of a cough, so this led to the development of the fifth model.

The fifth model was designed to combat the low velocity of the spray. Before the making of the fourth model, the first pulley was slightly out of line with the pump, causing some of the vertical velocity to be lost as increased friction and horizontal velocity. Not only did this lessen the efficiency of the design but it was also potentially damaging to the pump. The unnecessary movement of the pulley lead to the need for a sixth model to be tested.

The development of the sixth model was when two of the greatest problems in the model were fixed. The model was tiresome to operate and could cause damage to the pump over sustained usage. During this phase, every time the model was used the rope would pull onto the pump with a force of 98.1N. Although pumps are designed to be strong, there was a possibility that the repeated force could cause the plastic casing of the pump to buckle, damaging it beyond repair. The solution to this was to create a stopper, to prevent the pump from every being fully extended. The rope was attached first to the handle of the pump, and then to the base. It was arranged so that when the rope was fully stretched, the pump was still a few centimetres away from full stretch. This prevented the pump from colliding with the plastic casing at full speed. The other issue was one of reproducibility. Before this model, the method to use the model was to manually pull a weight off a bar. This left plenty of room for human error and meant that each test could not easily be reproduced. The new trigger mechanism fixed this problem, using a quick release system, so the string could be kept under tension and the model operated quickly.

A seventh model arose from problems relating to the wetting of the cloth in the mouth when using the sixth model. The area of the cloth that covered the hose would often not be reached by the water when the cloth was wetted, leading to issues in producing an aerosol spray. The solution for this problem was to change the location of the cloth. Before this change the cloth had simply been inserted into the mannequin's mouth. The wetting of the cloth caused the majority of the water to simply flow down the mannequin's chin. To solve this, the cloth was removed from the mouth and stretched over the end of the hose. The cloth was then secured in place with a rubber band and the hose was replaced into the mouth. Now, in order to operate the model, the water was squirted through a nostril to reach the cloth. This modification led to much improved efficiency of the model and allowed for the eighth and final problem to be fixed.

The final problem to fix related to the safety of the operation. When operating the first models, you had to hold the apparatus in place during operation to prevent it from falling over. When moving the ten-kilogram weight off the crossbeam, it was required to hold onto the model simply to drag it off. The need for this had now gone. The apparatus was sufficiently unsteady as to fall on the scientist during operation, which was a large flaw. The correction of this led to the last model. In this model, the base had been changed for greater stability by adding another diagonal to the base, preventing it from being able to fall. The model was then tested for the final three times to obtain enough data to compare to a human droplet spread.

There were issues in the measurement of the coughing, most involving the measurement. The camera used was that of a phone, resulting in low-quality photos with the colour slightly distorted. The different colours could still be picked out, however. The other issue was in the accuracy of the measurements. In a human cough, many of the droplets are too small to see. This causes a problem when measuring, as if the droplets are too small to be picked up by a human eye, they were unable to be measured. With another method of measurement, it would be possible to pick these up (Malvern Panalytical, 2020), but Cobalt Chloride is a cost-effective way of picking up the larger ones without requiring any calibration or specialist equipment.

One of the most important measurements for the similarity between the human and modelled coughs is the droplet spread. In the experiment, the shape of the spread of both coughs are similar. There is a large cluster of droplets at the base of the paper, with few, smaller droplets reaching the furthest. Between the two, the stimulated cough reached further, with the mean greatest length over the tests being 31.2cm, and for the human it was 28.3.
The mean of all the droplets is similar between all the experiments, falling between 10-20cm from the chin. A more precise measurement could be achieved using a high-precision camera to capture the droplet spread.

7.0 Conclusion

The design worked and can easily be adapted by those who need it to suit their own methods of blowing air through the mouth. Scientists with access to an alternative mechanism for delivering a standardised breath of air can simply re-wire the hose to the output rather than using a pulley system. Some trial and error may be required to find the optimal velocity for the cough.

For those scientists helping the world by creating and testing facemasks, try using a model along the same lines as this one. The human face of the mannequin allows for facemask fit, and the pump/fan makes for good standardisation. It is a hygienic, fast, and realistic way of modelling coughs without any human involvement.

This model is only a part of an experiment to test the efficiency of facemasks, a further study is needed to use this model. The importance of PPE for our healthcare workers means that testing it is essential. This model allows for complete standardisation of testing, with the ability to vary the volume of water and speed of air. The differences between coughs, sneezes and regular breathing mean that this ease of variation is essential.

8.0 References

Bibliography

Bureau of Meteorology, 2020. *Observations for Wynyard.* [Online]
Available at: http://www.bom.gov.au/places/tas/wynyard/observations/wynyard/
[Accessed 8 September 2020].
Fischer, E. P. et al., 2020. *Low-cost measurement of facemask efficacy for filtering expelled droplets during speech.* [Online]
Available at: https://advances.sciencemag.org/content/early/2020/08/07/sciadv.abd3083
[Accessed 1 September 2020].
Malvern Panalytical, 2020. *Spraytec.* [Online]
Available at: https://www.malvernpanalytical.com/en/products/product-range/spraytec?utm_source=MaterialsTalks&utm_medium=blog&utm_campaign=null&utm_term=51504&utm_content=entryContentLink
[Accessed 9 September 2020].
SeaFM, 2020. *'Borderline' test in the state's south.* [Online]
Available at: https://burnie.seafmtas.com.au/component/tags/tag/coronavirus
[Accessed 11 July 2020].

9.0 Acknowledgements

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- Dr. Brady Tassicker, …, for supervision and help with the usage of power tools and techniques used to construct the mannequin, as well as valuable design advice.
- Mr. Hurkett, Laboratory technician, Marist Regional College, for preparing the Cobalt Chloride paper used in the tests.

10.0 Appendices

App 1:

Risk Sheet

RISK ASSESSMENT for PRACTICAL INVESTIGATIONS BHP 2020

Practical Activity: a brief description of what is planned

Experiments:

The experiment planned is an engineering investigation into the possibility of modelling human coughs. A model will be built and tested using Cobalt Chloride paper for measurement.

What are the possible Risks?

List the Hazards present in this activity that could pose a Risk.

Give each Risk a Risk Rating (eg High Risk, Medium Risk, Low Risk).

Cobalt Chloride paper: Cobalt Chloride has known health risks. These include risk of cancer, damaging fertility and being toxic if swallowed. It can cause breathing difficulties and allergy symptoms. It is suspected of causing genetic defects. -High risk. Tool used in the construction of the model: Power tools will be used in the construction of the model. -Low risk	Consider: Chemical Thermal Biological Sharps Electrical Radiation Other Hazards

Control Measures?

Give details of how these risks will be managed.

The risk of the Cobalt Chloride paper will be managed by following safety guidelines associated with it. The paper is less toxic than its aqueous equivalent. The student will not touch the paper at any time, and gloves will be worn at all times when the paper is handled by a supervising adult.

The student will be supervised with some power tools, and others will be done by the supervising adult.

Are there any activities that will require adult/ teacher supervision?

Both the usage of the power tools and the testing of the model using the Cobalt Chloride paper will need to be supervised.

Facilities and Services that will be needed to do this activity safely.

Services	PPE	Safety Equipment
	Rubber gloves Safety Glasses	

Disposal of Wastes and Cleaning Up

Are any wastes or hazardous products produced in this activity? If so, how will they be disposed of?

Yes. Cobalt Chloride is very toxic to aquatic life. The paper will be given to the school for safe disposal after use.

Risk Assessment indicates that this activity can be safely carried out.

This Risk Assessment has been carried out and checked by the following:

Student's Name (please print):	Signature:	Date
Penny Tassicker		10/09/20
Teacher/ Supervisor Name (please print)	Signature	Date
Brady Tassicker A Burke	Ann B Burke	10/09/20

This Risk Assessment was opened on commencement of project (June 2020) and closed on completion (Sept 2020).

All chemicals used (cobalt chloride) had MSDS sheets that were within their review period (up for review in 2021)

References for MSDS Information:

https://beta-static.fishersci.com/content/dam/fishersci/en_US/documents/programs/education/regulatory-documents/sds/chemicals/chemicals-c/S25851.pdf