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# **Sterilization of Medical Equipment in a Third-World Country**

A Minor Field Study in Linga Linga, Mozambique

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## Sterilisering av medicinska instrument i ett utvecklingsland

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## Abstract

The non-profit organization Project Vita has recently built a maternity clinic in Linga Linga, where the medical instruments to be sterilized are boiled in water for an hour. The fuel needed to boil the water is wood, which is a scarce resource. This is why, according to the healthcare worker that was interviewed in Mozambique, it is desirable to have an electric-powered solution to sterilise the medical instruments.

After research on the different sterilization techniques that exist, the conclusion was drawn that the safest way to sterilise is by the use of an autoclave. However, it would be difficult to implement and maintain an autoclave in Linga Linga. Therefore, it was proposed to build an autoclave using a pressure cooker. Through experimentation, different programs, times and pressures were tested to find out if a pressure cooker could sterilise a common object. It could be concluded that theoretically, it seems that the pressure cooker reached a temperature of over 121 °C. However, the pressure could not be measured nor was a biological indicator, that could indicate if an autoclave or pressure cooker does sterile, used.

This project was to be done in Mozambique, but because of COVID-19, a travel ban was set in motion and universities and laboratories had limited access, thus limiting the project. As a result, it is still unclear if a pressure cooker can be used to sterilize medical instruments.

**Keywords:** Pressure cooker, sterilization, Mozambique, Linga Linga, Autoclave



## Sammanfattning

Den ideella organisationen Project Vita har nyligen byggt en förlossningsklinik i Linga Linga, där de medicinska instrumenten steriliseras genom att koka dem över öppen eld i en timme. För att koka vattnet, behövs ved, som är en bristvara. Enligt vårdpersonalen som intervjuades i Moçambique, är det därför önskvärt att byta ut denna metod mot en som är eldriven.

Efter en undersökning av de vanligaste steriliseringsteknikerna som finns, drogs slutsatsen att det säkraste sättet att sterilisera är med hjälp av autoklav. Det skulle dock vara svårt att införskaffa och hålla igång en autoklav i Linga Linga och därför föreslogs det att bygga en mindre autoklav utav en tryckkokare. Genom experiment testades olika program, tider och tryck för att ta reda på om en tryckkokare kunde sterilisera ett gemensamt instrument. Slutsatsen som då kunde dras är att det teoretiskt sett är möjligt för en tryckkokaren att nå en temperatur över 121 °C och därmed kunna agera som en tryckkokare. Dock kunde trycket inte mätas och inte heller användes en biologisk indikator för att påvisa att en tryckkokare kan sterilisera instrument.

Detta projekt skulle utföras i Moçambique, men på grund av COVID-19 sattes ett reseförbud och universitet och laboratorier hade begränsad tillgång, vilket begränsade projektet. Därav, är det ännu inte påvisat att en tryckkokare kan användas för sterilisera medicinska instrument och därmed fungera som en autoklav.

**Nyckelord:** Tryckkokare, Sterilisering, Moçambique, Linga Linga, Autoklav



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## Abbreviations

World Health Organisation = **WHO**

Centers for Disease Control and Prevention = **CDC**

U.S. Food and Drug Administration = **FDA**

Ultraviolet = **UV**

Ultraviolet Germinal Irradiation = **UVGI**

Sterility Assurance Level = **SAL**



# 1 Introduction

The country of Mozambique is designated by the United Nations [1] as one of the Least Developed Countries. Despite its rich farmland and untapped sources of coal and natural gas, the country is still suffering from the effects of a 16-year civil war that ended in 1992 [2\*]. SIDA [3\*], shows that while Mozambique has made considerable progress in reducing poverty, inequality has increased since the most vulnerable part of the population have not been able to access the few but slowly increasing opportunities.

The non-profit organization Project Vita finds solutions to the everyday challenges that the people of Mozambique face, including the the lack of access to healthcare. According to their own website [4], they are currently helping to build a maternity clinic in Linga Linga, a village with only 1 200 residents. By building the clinic, together with the local government and traditional leaders of Linga Linga, Project Vita is taking the first step to give the women of the village the option of a safe and sterile place to give birth.

The second step is to replace the current sterilization technique: a heat procedure where the instruments they wish to sterilize are put over an open fire. This technique requires the patients to bring their own firewood, which is a scarce resource. With the help of project Vita and with the request from the local health director, this project explores different sterilization techniques and introduces a prototype of a new sterilization technique that is meant to be reproduced sustainably at low cost by the residents of Linga Linga to improve their quality of life.

## 1.1 Aim

The purpose of this bachelor thesis is solving the sterilization issue in rural areas in Mozambique by replacing the current dry-heat sterilization technique with a method that is sustainable, safe and efficient. The research questions looked into are:

- What is the most effective method of sterilization in low and high resource settings?
- What alternative methods are there to sterilize instruments?
- Can the alternative methods be recreated by the clinical staff in Linga Linga?

## 1.2 Limitation

This project is limited by the resources that are accessible to Linga Linga's residents. The prototype that was made during this project was only tested on the equipment used by the medical staff in Linga Linga's maternity clinic.



## 2 Background

Jacobson [5] explains that in order to prevent disease transmission, most medical and surgical devices used in healthcare facilities need to undergo sterilization: the destruction of all microorganisms, including the bacterial spores. Stated on the same source, is that this can be achieved by heat sterilization, chemical sterilization or radiation sterilization.

### 2.1 Heat sterilization

Heat sterilization can be achieved either by dry or moist heat, using the fact that temperatures above 41°C breaks the interactions in most proteins, leading to their denaturation [5].

#### 2.1.1 Moist heat sterilization

According to Centers for Disease Control and Prevention [6] (CDC), the principle of moist heat sterilization is the most environmentally friendly and most common sterilization-principle in healthcare. It can be accomplished in an autoclave, which CDC describes as a device that exposes items to heat in the form of dry saturated steam, at the required temperature and pressure for the specified time. The effect of an autoclave depends mainly on two factors: a sufficiently high temperature being reached for a sufficiently long time and all air being evacuated and replaced with steam, Vårdhandboken describes [7].

There are various types of autoclaves, but all of them undergo the same three phases of a sterilization cycle [9]:

1. **Purge Phase:** The door locks to form a closed vessel, which then gets heated. When the temperature reaches 100°C, the water boils, generating steam. Because the vessel is closed, all air inside the valve gets exchanged for steam. As the steam enters the chamber through a pressure-valve, it fills the upper area as it has a lower density, which causes the existing air in the chamber to be pressed down to the lower area. Because of the high pressure this causes, the air is forced through a thermostatic trap containing a temperature sensor.
2. **Exposure Phase:** The control system is programmed to close the pressure-valve when the sensors detect a certain pressure and the sensors in the thermostatic trap detect a certain temperature. As a result, the pressure and thus also the temperature increase to the required value. The program then keeps the temperature constant for the required time, with the help of a trim valve which releases the excess steam. To achieve sterility, the recommended times and temperatures during this specific phase are given by Vårdhandboken [7] to all clinics in Sweden. The specifications are 121°C for 15 minutes or 134°C for 3 minutes, depending on how sensitive the object to be sterilized is sensitive to heat.

3. **Exhaust Phase:** With the help of the sensors and the control system, the valve opens and empties the vessel of steam. As a result, the pressure drops and the door opens.

The Ideal Gas Law states that the temperature of a gas, held at constant volume, is directly proportional to its pressure [9]. This means, the higher the pressure gets in the autoclave chamber, the higher the temperature gets. Thus, Franks Hospital [9] has calculated that when a temperature reaches 121°C the pressure is always 100 kPa and when it reaches 134°C, the pressure is always 200 kPa. They state that ideally, it would be enough to look at either the pressure gauge or the temperature, to know if the autoclave works correctly, but in practice most of the autoclaves have both.

### 2.1.2 Dry heat sterilization

According to CDC [6], the principle of dry heat sterilization has been around for the longest time and it can be accomplished by hot air oven, incineration or flaming. It is explained, by CDC, that these methods require exposure time between 1 to 2.5 hours and temperatures between 150°C and 170°C.

### 2.1.3 Preparation for heat sterilization

Preparation for heat sterilization is of high importance, according to CDC [6], since the effectivity of a sterilisator depends on the amount of the present microorganisms on the item before sterilization. It is explained by the same site, that this preparation is done mechanically, for instance with a solution of soap or saline.

According to retailer CardinalHealth [10], before the start of the sterilization cycle, the object to be sterilized must be packaged in a way that allows steam to penetrate and reach it but at the same time protects it from microbes, when the object is handled after sterilization. In today's healthcare, there are sterilization pouches in many different forms that are used for this purpose. These sterilization pouches are available worldwide, and there are many brands that produce these pouches, for example Amazon, Getinge and other online retailers. The most common pouches have one transparent side made out of 2 ply laminate film (plastic) and another side made out of 70 gsm (Gram per Square Meter) paper [11].

## 2.2 Chemical sterilization

There is a wide array of chemicals used for sterilization of medical and surgical equipment, and they are either in gaseous or liquid form, Jacobson [5] explains.

### 2.2.1 Gas sterilization

As stated by Jacobson [5], Formaldehyde in gas-form is primarily used for sterilization purposes. The mode of action for formaldehyde is explained by MWI Animal Health [12] to be that it targets the amino and sulphydral groups of protein and inhibits the growth of the microorganism.

According to CDC [13], the process of gas sterilization includes a vacuum chamber where an object may be placed. When the chamber is sealed, a pump pumps in formaldehyde and steam. The mixture then fills up the chamber, making the temperature in the chamber between 70-75°C, with a relative humidity of 75% to 100%. After that, a pump pumps in a constant flow of steam and air to clean the object of any chemical residue.

A gas that allows sterilization at low temperatures is ethylene oxide, Jacobson states [5]. Jacobson explains that it may be used in hospitals for re-sterilization of valuable disposable items, which takes takes 3-5 hours. However, it is also clarified that this process is avoided since ethylene oxide is both explosive and toxic.

### 2.2.2 Liquid sterilization

For sterilization using liquid, the objects are first immersed in liquid chemical germicide for a couple of hours depending on the chemical, and then thoroughly rinsed with sterile water, Jacobson [5] illustrates.

As stated by the U.S. Food and Drug AdministrationThe (FDA) [14], the most common liquid chemicals that are used for sterilization, are formaldehyde and glutaraldehyde. However, it is also clarified that sterilization by liquid formaldehyde is an unusual method. The main reason is explained to be that formaldehyde as a liquid is highly dangerous to humans. Moreover, the FDA explains that liquid formaldehyde may chemically damage objects and that the process takes between 3 hours to 12 hours.

## 2.3 Ultraviolet sterilization

Ultraviolet (UV) light is defined by Nationalencyklopedin (NE) [15] as non-visible light with a short wavelength, between X-rays and visible light. Lindsley et al. [16] explain that UV-light with different wavelengths can harm different organisms in different ways. The example that is drawn to clarify this is that UV-B causes a breakage of the molecular bonds in the DNA in microorganisms. This leads to a loss of action for the organism and thereby death. Lindsley et al. state that the fact that this process can take place in bacterial cells (or spores) and viruses, is used for sterilization.

UV sterilization is often referred to Ultraviolet Germicidal Irradiation (UVGI). According to Lindsley et al., the process is considered simple, containing

minimal steps. An object is exposed to UV-B light under a certain amount of time in isolation. It is also explained, by the same source, that the effectiveness of the process is determined by time and intensity of the UV-rays, but commonly supplies clinical sterile results. As stated by Lindsley et al., anything may be sterilized by UVGI, preferably large bodies of water, sealed rooms, or food.

According to Lindsley et al., the method of UV sterilization may be used for large objects or for object sensitive to heat or water. The advantages are, according to Lindsey et al, that the method is inexpensive, simple to use and does not harm humans who may be exposed for a short time. On the other hand, the problem with UVGI is that it is not time efficient for bacterial dense objects. Another problem that is explained is that the UV-light is generated by Mercury-containing lamps. However, mercury is dangerous to humans and animals because it attacks the nervous system and digestive system, thus making it illegal in most parts of the world.

## 2.4 Sterility Assurance Level

For a medical device to be considered sterile, the probability that a microorganism is present on or in the item should be equal to or less than one in a million, CDC [17] states. This probability is referred to as the sterility assurance level (SAL), and is commonly calculated to estimate the effectiveness of a sterilization method and assure sterility. According to CDC, SAL is expressed as 10 to the power of  $n$  ( $10^{-n}$ , where  $n$  is 1,2,3,..., $n$ ), meaning that the probability of finding a non-sterile unit is 1 in  $10^n$ .

## 2.5 Sterilization indicators

As explained by CDC [17], to ensure effective sterilization of objects, regular controls must be made on the method or instrument used. This has led to the development of a wide array of methods to test if the desired level of sterility is achieved. The most common test that is used in the Swedish healthcare is described by Vårdhandboken [7] to be the Bowie-Dick test, which assures that the sterilization device itself works. Furthermore, the device could be monitored using mechanical, biological, or chemical indicators, as stated by CDC.

### 2.5.1 Bowie-Dick test

The Bowie-Dick test is an easy test to prove that the air-ventilation in an autoclave is working adequately, as this is done by proving that all air is gone when reaching a state of vacuum. According to Consolidated Sterilizer Systems [18], the test is a small package (0.05 kg) that consists of layers of paper. There is a chemical indicator between the layers of paper that changes color when all the air in the package is gone. Vårdhandboken [7] states that



the test should be placed by itself in the sterilization chamber at the lowest shelf right next to the drain or the air vent. The Bowie-Dick test only needs to be in the chamber for a few minutes (4 min) and only the fastest cycle should be applied. After a short cycle, the package will yield to results, indicating a failing or passing outcome. It is recommended by the Vårdhandboken to perform this test every day.

According to Consolidated Sterilizer Systems [18], an unused test is yellow and changes color to black when all air in the package is gone. If the air ventilation is working then the test will turn black all over. If it only turned black in some places but is still yellow in other places then the test has failed, and the sterilization machine should be controlled.

Furthermore, Vårdhanboken states that the reason for a failed test could be poor air ventilation. A change in the ventilation or the filter could solve the problem. Another reason could be the formation of condensation, that arises when the steam traps do not work properly.

The test is of great importance because it is an indication if air is leaking in or out of the chambers during a sterilization cycle. This could compromise the cycle and lead to ineffective sterilization of the object inside the chambers. Besides being reliable, the test is both fast and cheap, thus making it optimal as an everyday test to use on autoclaves.

### **2.5.2 Mechanical indicators**

According to CDC [19], mechanical indicators are instruments that show the current state of an object. It may reveal the pressure or temperature of an object. If the object is digital, a mechanical indicator may search for problems in the program of the instrument or measure the current and voltage of the instrument (to prevent systematic errors that may damage the equipment). Most importantly a mechanical indicator is used to ensure a sealed autoclave where no air or other substances may leave or leak into the instruments when used, as stated by CDC.

### **2.5.3 Chemical indicators**

Chemical indicators may ensure that a certain temperature is reached. One chemical indicator is autoclave tape. By putting the tape on the object that will be sterilised or by putting a strip of tape inside an instrument, it will develop black stripes if the desired temperature, often 121°C, is reached inside the chamber [19,20]. The tape is used mostly in autoclaves because it is temperature sensitive [20]. The autoclave tape consists of a porous paper coated with a lead carbonated thermochromic dye [19]. If used correctly black stripes appear on the tape if the temperature reaches 121 – 134 °C.

Unfortunately, the autoclave tape does not indicate for how long a temperature is maintained in a cycle, only that it has been reached, as stated in Gnotobiotics [21]. Furthermore, it is explained that it does not indicate if steam has reached the object that is being sterilised. To conclude, autoclave tape is only an indication that a sterilization cycle will reach the temperatures of 121 – 134 °but not for how long they stay at that temperature nor if the object inside is getting sterilised.

#### 2.5.4 Biological indicators

According to Mesa Labs [22], biological indicators are a safe and accurate way to tell if an object is sterile or not. Biological indicators may come in different forms: stripe, stainless steel, or gel form. As explained by CDC, the forms of indicators depend on how thorough the test is. Stripes are used when testing a few common bacterial tribes and have short incubation time (24 hours). Gel indicators are used when the sterilization requires liquids for example chemical sterilization, where the stripes dissolves in chemicals [20]. Stainless steel forms are used when testing out instruments using UV-light, for the reason the steel will not affect the indicator or the bacterial tribes [20].

The most used bacterial tribes are *Geobacillus stearothermophilus* and *Bacillus atrophaeus* which are used in spore test regarding dry heat and steam sterilization [23]. According to Mikhail and Young [24], the reason for the use of these strains is because they have been proven to have some resistance to dry heat sterilization and steam sterilization. They explain, if these bacterial tribes are put through a sterilization cycle that works properly the bacterial tribes will be eliminated and thus telling if the equipment works or not. Furthermore, Mikhail and young describe what bacterial strain is used for what purpose, for example the strain *Bacillus pumilus* is used when testing UVGI, for the reason it is next to resistant to radiation. For heat sensitive methods the strain *Bacillus Subtilis* is used. Last, for liquid sterilization *Bacillus Smithii* is used.

McCormick et al. [25], describe that the biological indicators works in a way where known, common, active bacterial spores are rubbed on the body of the indicator and the indicator will be put inside the sterilization cavity. An explanation is given about the use of the indicators, the sterilization program will go on as usual and after that the indicator will be taken out of the cavity. The spores of bacteria will not be visible to the naked eye and after usage it may need between two to five incubation days to reproduce and be visible. It is further explained that after the incubation time the bacterial colonies that may have developed will be examined through a visual test from the user. The bacterial colonies can be identified by the user manual and tribes of bacteria are divided by visible lines or other barriers [23].

## 3 Method

This chapter will introduce the process of data collection, via the web, databases and interviews. With the help of the data collected the modification of the pressure cooker began to turn it into an autoclave. Unknown parameters as the pressure, sterility and functionality will be examined and evaluated with the help of chemical and mechanical indicators. The mechanical and chemical indicators will be inquired via the internet. All experiments and research were made in Sweden.

Depending on the conclusions drawn from the above-mentioned data, a manual will be written to describe the process of creating an alternative sterilization technique.

### 3.1 Information gathering

Information about Mozambique and the sterilization methods used there was collected, using the search motor Google, Google Scholar and PRIMO. The keywords used in searching for appropriate sources were "sterilization" "rural areas", "medical equipment" and "Mozambique". The sources used were government guidelines and university journals, that could be found on the net or university search service. This is to get impartial information on the subject. The same way sources about sterilization using a pressure cooker were searched for using the keywords "Pressure cooker", "Autoclave" and "At home sterilization". All the sources were relevant in time, to get a current picture of the situation in Mozambique and in rural areas, mainly in south-west Africa.

For the usage of certain indicators and other parts of the pressure cooker, the site of sale origin is used to get accurate information about the objects and to purchase them. The sites used were [www.blocket.se](http://www.blocket.se), [www.killerinktattoo.se](http://www.killerinktattoo.se) and [www.jula.se](http://www.jula.se). The pressure cooker was bought from Blocket, the sterilisation tools (autoclave tape and sterilisation pouches) from Killer Ink Tattoo and hardware (manometer and wire) from Julia. For the pressure cooker, the manual included was used as a source.

#### 3.1.1 Interviews

For accurate information about the sterilization of medical equipment in Mozambique, specifically Linga Linga, a contact person living there was contacted via email, Michel Olofsson. In the email, a questionnaire was attached with questions regarding the medical situation in Linga Linga. The contact person was asked to conduct the interview using the questionnaire and email the results of the interview. The interview was done with one nurse with previous experience in healthcare.

The questionnaire was developed in a way that it would be easy to understand

for both caregivers and carers. Everything that was unnecessary was peeled off to get an understandable form, and only twelve questions were asked. The questions asked were:

- What is your preferred method of sterilization?
- For how many years have you used this method?
- What kind of fuel is used in the method? (Wood, oil, gas, solar panels, etc.)
- What kind of instrument do you sterilize?
- How often do you sterilize the medical instruments?
- How long does it take to sterilize an object?
- Is the method safe to use for both patient and user?
- Is the method easy to use?
- Are you satisfied with the results?
- How often does it need maintenance?
- How often is it controlled that it works?
- Would you use another sterilization method if there was one available or would you like to continue using the method you are using now?

The first part is strictly practical, where it was asked what methods they use to sterilize. What the method uses for the energy source, and how safe it is for the user. Secondly, the medical staffs routines and access to resources was investigated. They were asked what a typical sterilization cycle looks like. How often is it checked to see that it works? Does it need any maintenance by a professional? Lastly, the personal opinion of the medical workers was asked for. Do they believe that their solution at the moment is ideal or can it become better? In that case what kind of improvement is needed? Would they like another alternative method?

## 3.2 Building of Prototype

In this section an explanation of the optimization and use of the pressure cooker is explained. Furthermore, a detailed explanation of the different programs and times that were tested will be explained.

### 3.2.1 Finding and adjusting a pressure cooker

A pressure cooker was searched for on secondhand marketplaces online. The sites used to search for a pre-owned pressure cooker were [www.blocket.se](http://www.blocket.se) and [www.facebook.se](http://www.facebook.se). The requirements for the pressure cooker was for it to be electrical because according to the interview with the health worker, they would like an electrical solution. Besides that requirement there were no other specific conditions a pressure cooker need to fulfill. A pressure cooker was found on Blocket and bought for 500 SEK, called "Pressure Cooker" from the brand *Feller* and model PC 610 (See Figures 2, 3 and 4). The pressure cooker required power supply of 220 V and a power of 1000 W, and it could also hold up to 6 litres of liquid, but this is not a requirement. A grill with a diameter of 7.6 cm was included in the pressure cooker. The grill could be taken out from the inner chamber because of its small size. The grill had no handles so a handle was made by using two 24 cm long wires (See Figure 1). With the wires over the grill, the grill could be taken out like a basket and the user will not have to touch the grill (See Figure 1).

**OBSERVE!** It was later on concluded that a wrong installation of the manometer might lead the pressure cooker to explode. It is highly advised not to tamper with the ventilator (safety valve) of a pressure cooker and to avoid recreating the following steps:

The pressure cooker needed an adjustment to measure the pressure inside the pressure chamber. A manometer from the company Officine Meccaniche ANI, and with the diameter of 6.35 millimetres was installed on the lid of the pressure cooker (See Figure 5). Commercial pressure cookers have a ventilator on top of the lid to let the pressure out, which the Feller pressure cooker also had. This ventilator was screwed off and the manometer was screwed on instead. The manometer was used to measure the pressure in the pressure cooker during every program, and the unit the pressure was showed in was psi (pound force per square inch). The pressure in psi was converted to Pa (pascals) as  $1 \text{ psi} \approx 6900 \text{ pascals}$ . The pressure cooker activated by plugging it into a socket, pressing the on button and pressing the desired program. When the pressure cooker was on the manometer would show the pressure in the unit bar. Only the highest pressure was observed and written down.



Figure 1: The metal grill with the wire handles.



Figure 2: The pressure cooker from the side.



Figure 3: The pressure cooker from above.



Figure 4: The inner chamber of the pressure cooker.



Figure 5: The pressure cooker with a manometer installed on the lid.

### 3.2.2 Testing of the Pressure cooker

After building the prototype of a sterilization machine, it was tested. The first tests included chemical indicators to observe if the pressure cooker reached a desirable temperature. The chemical indicator used was autoclave tape.

The pressure cooker consists of two containers one outer container and one inner. The instruments must be sterilized in the inner container. The inner container has a diameter of 23.8 cm and a depth of 15.3 cm. Three strips of 7 cm autoclave tape were each cut and placed on the sides of the inner container, and with 5 cm spacing between the three strips, the autoclave tape being from a company in Germany called "KillerInk", and purchased from their website [killerinktattoo.se](http://killerinktattoo.se). 500 ml of cold water from a faucet was poured inside the inner chamber, thus submerging the stripe closest to the bottom of the chamber (See Figures 6 and 7).

The pressure cooker had 8 programs to chose from, and for every program there were 3 different settings for the pressure called "LOW", "MEDIUM", and "HIGH". The pressure for the setting "LOW" was 55.16 kPa, for "MEDIUM" 75.8 kPa and for "HIGH" 100 kPa. The high pressure option was used in every test, because it was believed that the temperature will increase with an increasing pressure. This was motivated by the ideal gas law, as long as the volume is constant the temperature will increase if the pressure increase.



Figure 6: Three pieces of autoclave tape on opposite sides, before pouring the water in and before being exposed to any type of pressure and heat.





Figure 7: Three pieces of autoclave tape on opposite sides, one under water, before being exposed to any type of pressure and heat.

A time limit was chosen based on how long an autoclave cycle is and how long it takes to sterilise in Mozambique, according to the research and interviews made. It is beneficial to keep the the time as short as possible. The programs that had a time minimum limit of more than 2 hours were not used. Neither were programs that could endanger objects or people used. Thus, only 5 programs remained. The programs were tested according to the order in Table 1.

Number of Test	Program	Time (Hour)
Test 1	Porridge/Soup	2
Test 2	Meat/Chicken	2
Test 3	Bean/Tendon	2
Test 4	Rice	2
Test 5	Steam/Stew	2

Table 1: Table of the different programs, with time in order of test.

After every test the autoclave tape was observed and searched for black stripes. The black stripes indicate that the chamber reached a temperature at around 130 °C.

Since the pressure cooker had a minimum set time of 2 hours, the chosen program was cancelled after a set amount of minutes. A timer was set for the desired time and when the time was up the program was stopped by pressing the button "Keep Warm/Cancel" on the pressure cooker. To be able to open the pressure cooker the pressure must be lowered. That was done by turning the vent slightly to the right and letting the pressure leave. It took 30 seconds for the pressure to decrease and thus being able to open the lid. This was repeated four times; after 15 minutes, 30 minutes, 45 minutes and 60 minutes.

Before starting putting objects inside the pressure cooker sterilization pouches were bought from the website and brand KillerInk Tattoo. The sterilization pouches came as a 100-meter long roll and 10 centimetres wide, where they have to be cut to the desired measurement. The pouches had one side made of plastic and the other side made of paper. For the first test, a teaspoon was decided upon to try and sterilise, because it is metal and it is small enough to fit in the pressure cooker. The sterilization pouch was cut to be 13 centimetres and to fit the spoon inside.

The spoon was put inside the pouch and sealed off with autoclave tape. The tape was put horizontally on the sides to ensure that the spoon was completely sealed. The spoon (inside the pouch) was put inside the inner chamber on the grill, the lid to the pressure cooker was put on, and the desired program and time were chosen. When the program was finished, the spoon got taken out of the chamber using a pair of metal tongs. Observation on the spoon and autoclave tape was made. The results were recorded.

The next step was to try the biological indicators to examine if the pressure cooker reached the desired sterility. First, the petri dish containing *Geobacillus stearothermophilus* was put inside a plastic pouch, cut to fit at 20 cm, and sealed using autoclave tape. The program and time were selected and the pouch containing the petri dish was put on the grill inside the chamber. Second, when the program was done, the pouch was inspected for any external damage and was left in an incubator with a temperature at around 40 degrees Celsius, for 48 hours. The same method was used for the remaining petri dishes. Last, after 48 hours the petri dishes were examined via a visual test to see if any bacterial colonies had been made, and if so how many colonies were there. The results of the process were recorded.

### **3.3 Instruction manual on how to build and operate the autoclave**

An important part of the project was to write simple instructions to the healthcare staff in Linga Linga on how to make an autoclave from a pressure cooker and metal stripes. Furthermore, another set of instructions were written, but on how to prepare the equipment for sterilization, how to use the steriliser and what the timer should be set on.

## 4 Results

The results from the interviews and modification of the pressure cooker are presented in this section. The outcome from the mechanical and chemical indicators, also the bacterial indicators are tabulated and explained briefly. Different programs in the pressure cooker are evaluated and tabulated for easier understanding.

### 4.1 Sterilization in Mozambique

When searching for how sterilization is done in Mozambique almost no reliable information was found. There was neither information about sterilization nor healthcare in Mozambique. The information was minimal about the sterilization of medical equipment in developing countries.

#### 4.1.1 Interview from a health care worker in Linga Linga

The questionnaire was sent on 9/5 – 2020 and the response was received 13/5 – 2020. The following answers were given from the interviewed nurse:

- What is your preferred method of sterilization?  
*An electrical system is preferred, but as for now firewood is used to boil water in a saucepan and putting instrument in it for sterilization.*
- For how many years have you used this method?  
*Throughout 2019 this has been the preferred method.*
- What kind of fuel is used in the method? (Wood, oil, gas, solar panels, etc.)  
*Wood.*
- What kind of instrument do you sterilize?  
*Birth Kits and metal instruments are being sterilized.*
- How often do you sterilize the medical instruments?  
*Once a week.*
- How long does it take to sterilize an object?  
*Around one hour.*
- Is the method safe to use for both patient and user?  
*Yes.*
- Is the method easy to use?  
*No. The search for wood and the transport of it is the task of the health care workers.*
- Are you satisfied with the results?  
*Yes.*

- How often does it need maintenance?  
*The only thing that needs maintenance is a saucepan that is cleaned by the healthcare workers on the inside.*
- How often is it controlled that it works?  
*Only once. An indicator stick that is put in the water and turns a different color when it is done.*
- Would you use another sterilization method if there was one available or would you like to continue using the method you are using now?  
*Yes, they would like a method that is easier and faster.*

The answers given gave enough information about the situation in Linga Linga. The healthcare workers must find firewood to heat up water and sterilize metal instruments and birth kits. This method is demanding and takes about 1 hour every cycle. According to the interviewed nurse there is room for improvement.

## 4.2 Assessment of the most common sterilization methods

The top sites/results from the research done on the net about sterilization were the FDA's website, journals, and other government sites. The majority of them concluded that an autoclave was the safest and easiest option for sterilization (See Table 2).

Method	Advantages	Disadvantage
Heat-sterilization	<ul style="list-style-type: none"> <li>-Rapid cycle time</li> <li>-Nontoxic to patient, staff and environment</li> <li>-Cycle easy to control and monitor</li> </ul>	<ul style="list-style-type: none"> <li>-Destroys heat-sensitive instruments</li> <li>-May leave instruments wet, causing them to rust</li> </ul>
Chemical-sterilization	<ul style="list-style-type: none"> <li>-Simple to operate and monitor</li> <li>-Low temperatures that makes it suitable for most medical materials</li> </ul>	<ul style="list-style-type: none"> <li>-Long durations</li> <li>-The used chemicals are toxic and flammable</li> </ul>
UV-sterilization	<ul style="list-style-type: none"> <li>-Low maintenance and easy handling</li> <li>-Low operating costs</li> <li>-Low temperatures that makes it suitable for most medical materials</li> </ul>	<ul style="list-style-type: none"> <li>-Low efficiency since the radiation is not penetrating</li> <li>-Long exposure duration may destroy the material</li> <li>-Requires mercury, making the method difficult to manufacture</li> </ul>

Table 2: A list of advantages and disadvantages of the most common sterilization methods.

### 4.3 Testing of program, time and pressure of the pressure cooker

The pressure cooker obtained had 8 different cooking programs, excluding the settings. The programs were "Yoghurt", "Porridge/Soup", "Meat/Chicken", "Bean/Tendon", "Crispy rice", "Rice", "Steam/ Stew" and "Slow cook". Almost every program had a time minimum set of 2 hours, but "Yoghurt" had a time limit at 9 hours and "Slow cook" at 5 hours, thus excluding them from the experiment. The two settings "Timer" and "Mode" were used to increase the time (up to 23 hours) and "Mode" to choose between the pressures of "Low", "Medium", and "High". The option "Crispy rice" was excluded for the reason it might burn the object inside the chamber. For the remaining five programs a table was made to indicate if they reached the desired temperature, by observing black stripes on the autoclave tape (See Table 4 and Figure 8).

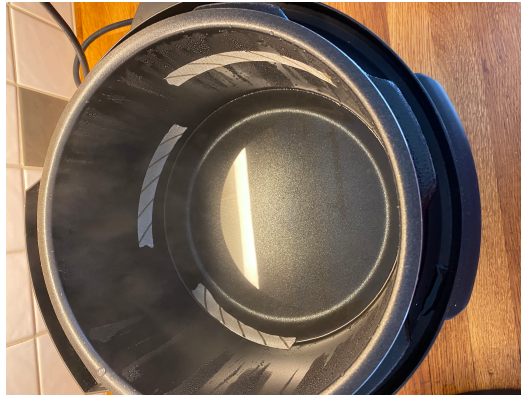


Figure 8: The black stripes indicating that a temperature between 121 – 134 °C was reached, after 30 minutes.

Number of test	Program	Time (Hours)	Black stripes (Yes/No)
Test 1	Porridge/Soup	2	Yes
Test 2	Meat/Chicken	2	Yes
Test 3	Bean/Tendon	2	Yes
Test 4	Rice	2	No
Test 5	Steam/Stew	2	No

Table 3: Table of the tests and programs. The far right column indicating if black stripes appeared on the autoclave-tape.

The program and setting fit for use, was "Porridge/Soup", "Meat/Chicken", and "Bean/Tendon". There was no difference in the result between the three programs, thus any of the three programs may be chosen.

As for the time, all programs had a limit of 2 hours minimum. Thus different times were tested. The absolute minimum time the pressure cooker needed to turn the autoclave tape stripes black was 30 minutes. For the lowest (15 minutes) the stripes never turned black thus indicating it never reached desired temperature.

Number of test	Program	Time (Minutes)	Black stripes (Yes/No)
Test 1	Porridge/Soup	15	No
Test 2	Porridge/Soup	30	Yes
Test 3	Porridge/Soup	45	Yes
Test 4	Porridge/Soup	60	Yes

Table 4: Table of the tests and programs. The far right column indicating if black stripes appeared on the autoclave-tape. For this time test only the "Porridge/Soup" program was used, to try and keep the results as objective as possible.

The spoon wrapped in a plastic sterilization pouch and sealed with autoclave tape was examined for any internal or external damages for example if the pouch had teared. It could be concluded that from observing the pouch did not burst inside the pressure cooker nor did the spoon break or take any damage. The autoclave tape had black stripes thus indicating it reached the desired temperature of 121-130 °C, but according to the display the highest temperature reached by the pressure cooker was 126 °C for the whole cycle (See Figure 9).

#### 4.3.1 Pressure

The pressure could be chosen by choosing a level of pressure "LOW", "MEDIUM" and "HIGH". The pressure for the levels was 8 psi (55160 Pa) for "LOW", 11 psi (75800 Pa) for "MEDIUM" and 14 – 15 psi (100 kPa) for "HIGH". The pressures could be found in the manual that came with the pressure cooker.

The manometer showed that the pressure was 0 psi through every cycle and every program. It showed 0 psi whether the chosen pressure was "LOW", "MEDIUM" or "HIGH".



Figure 9: A metal spoon inside the sterilization pouch, sealed by autoclave tape. The autoclave tape had developed black stripes, thus indicating a temperature between 120-130 °C was reached.

#### **4.4 Instruction manual on how to build and operate the autoclave**

The process of how to optimize a pressure cooker to hypothetically function as a pressure cooker, was described in detail in an instruction manual (see Appendix 1). This manual, summarizes the execution of the project briefly and concisely and includes suggestions on alternative materials that can be used. It is intended to be used for further development of this study to answer the third research question of this project: "Can the alternative methods be recreated by the clinical staff in Linga Linga?".





## 5 Discussion

The results from the research and experiment for this project are discussed in this section. First, the situation around the world regarding COVID-19 is considered and an explanation is given on how it has affected the thesis. Second, the result from the interview, the research and the construction of the prototype are explained. Statements on how the pressure cooker performed and if it met the requirements for safe sterilisation, and sustainable standpoints regarding the use of a pressure cooker are given. Third, the method and the indicators used are evaluated. Last, the sources of error are examined and discussed.

### 5.1 COVID-19

At the beginning of the year 2020, a pandemic virus halted this project. The infectious disease COVID-19 spread all over the world. The consequences of this disease are that almost all the borders closed, and travelling was suspended. Because of COVID-19, the project could not be performed in Mozambique as planned. The planned trip to Mozambique was on 29 May, but Sweden had suspended all overseas travel until 15 July. This led to the project being scaled down and had to be carried out in Sweden. Fortunately, the interviews could be conducted in Mozambique thanks to Michel Olofsson who lives in Mozambique and could interview health care workers. Even in Sweden, movement was restricted, making it more difficult to carry out experiments and obtain materials.

The use of the pressure cooker and the testing of the pressure cooker to find the correct program had to be done at the home of the participants. Since most of the materials could be obtained, this work was made possible. However, because of the materials that could not be obtained, a biological indicator could not be made. As a result of not testing the pressure cooker with a biological indicator, it was not possible to confirm that the products that were inserted into the pressure cooker reached a level of sterility. Thus, the results must be taken with precaution because even though the mechanical indicators may give a satisfying result, it does not mean that the pressure cooker will sterilize the instruments.

Problems and limitations that arose due to COVID-19 are referenced to frequently in this chapter. There is a discussion on how it would differ if the interviews and building of a prototype were performed in Mozambique. Because the building of an autoclave from a pressure cooker was made in Sweden it is discussed about the experience of acquiring material and building an autoclave might differ from doing it in Mozambique.

## **5.2 Sterilization in Mozambique**

The information-gathering of sterilization in Mozambique and in developing countries did not yield any relevant results. This could be because this is not yet a global issue. Mozambique does not stand out and a search about the country is only resulting travel and tourist information that is subjective and irrelevant to the subject. It is believed that most developing countries have hospitals in the capital or bigger cities, and not in smaller villages, which leads to a decline in the need to find a solution to adequate healthcare and sterilization. This led to the main sources of this thesis and sterilization in Linga Linga to be Project Vita, Olofsson and the interview he had with a local healthcare worker.

### **5.2.1 Interview from a healthcare worker in Linga Linga**

Only one interview was conducted and it was conducted by Michel Olofsson from Project Vita. Olofsson has lived in Linga Linga since 2014 and is trusted in the community and thus could be trusted with doing the interview objectively. It is believed that the interviewed nurse did not feel any pressure to answer a certain way nor to lie, thus making her statements believable. The reason more healthcare workers could not be interviewed is because of the COVID-19 situation. It is of great importance to minimize interactions between individuals.

What would have been done differently if the authors of this report were in Mozambique, would be to interview more individuals to compare the answers between the workers and target specific problems they have. Most problems specified in this thesis have been based on one interview and information from Olofsson. The method used in Mozambique could be adapted to better fit the needs and the environment, but that is not possible at the moment.

## **5.3 Assessment of the most common sterilization methods**

The assessment of which method could work in the clinic in Linga Linga was made by comparing the different methods (See Table 2). To summarize the results, chemical sterilization was not preferred, for the reasons, it might be dangerous if the necessary precautions are not taken, and UV sterilization was not preferred because it requires mercury, which the residents have no access to, and as previously stated highly dangerous to humans and animals.

As a result, heat sterilization was assessed to be the most suitable method for the clinic in Linga Linga. Compared to steam sterilization, dry heat sterilization requires higher temperatures and longer times and is therefore considered ineffective. Thus steam sterilization was considered to be the most suitable method to reach the aim of this project.

Steam autoclave uses pressure, steam and heat to sterilize. A pressure cooker uses the same parameters, thus making it suitable to try. More specifically, the conclusion was drawn that a portable autoclave may be used in rural clinics, because of their simpler design in spite of their limitation to small instruments, such as needles. The pressure cooker may be small but according to the interview with the nurse only small metal instruments and birth kits are sterilized. Furthermore, the nurse wanted an electrical solution to the sterilization situation they have. For now, they have to gather wood to heat water. The use of a pressure cooker eliminates that problem. As mentioned earlier, a faster and easier way of sterilization was desired, because it took around an hour to sterilize and the gathering of fuel is challenging, as stated by the interviewed nurse.

The way they already sterilize in Linga Linga is like the use of a steam autoclave. Heating the water until it reaches a high temperature and boiling the instruments for about an hour. The use of an autoclave/pressure cooker might seem excessive, but from the results collected the time of sterilization can get as low as 30 minutes (See Table 4). Besides reducing the time by half, the nurse expressed the need for an electrical device to evade the collecting of wood. Taking all that into consideration a pressure cooker might be an alternative, and according to Michel Olofsson, pressure cookers are available in Mozambique. Unfortunately, the quality of the pressure cooker cannot be guaranteed, thus making this only a proposal. Another issue that might arise is the use of saltwater or regular water in the pressure cooker. For the experiment done in Sweden regular water from a faucet was used. In Linga Linga it was not stated what kind of water they used. If they use saltwater it might lead to calcification in the inner chamber if used frequently. This problem will not happen in the same extent if water made for consumption is used.

## **5.4 Testing of the Pressure cooker**

Two types of indicators were used to try and determine the characteristics of the pressure cooker: a mechanical and a chemical indicator. Once again, because of the COVID-19 pandemic, we cannot try out the pressure cookers in Mozambique nor can we work with them. The only reference is the EU-approved equipment used.

### **5.4.1 Mechanical indicator**

For the pressure, a mechanical indicator was used, a manometer. The pressure-cooker that was used already had a known pressure that it can reach so the manometer was not needed in this case. Firstly, it was difficult to install the manometer on the pressure cooker, and there were no other options for the measurement of pressure. Secondly, the manometer sometimes did not react on when the pressure was on and did not show what the pressure was or showed a

pressure that was too low to be plausible. Thirdly, according to the manual the pressure was already known. Lastly, if this was in Mozambique a manometer might not have been found and the pressure would not be measurable.

Because there was access to the material, the mechanical indicator was installed to further learn the exact pressure, even if it is not needed. Unfortunately, it did not succeed and it is advised to use a pressure cooker that shows the pressure digitally or that declares the pressure for future uses. Once again, it is advised against following the method explained in this thesis, with the installment of the manometer in the place of the ventilation. The ventilator is a security measurement in case the pressure reaches too high levels (higher than 100 kPa) the ventilator will open to let out the pressure. By installing a manometer there, this mechanism was eliminated. It could have led to a build up of pressure which would lead to the pressure cooker exploding. Fortunately, that did not happen while experimenting and writing this thesis, but it is not guaranteed that it will not explode. This can be avoided by buying newer models that have pressure sensors installed and a display of the pressure.

#### **5.4.2 Chemical indicator**

In the early stages, a chemical indicator was used, the autoclave tape. The autoclave tape indicated if the inner chambers of the pressure cooker reached a temperature between 121 – 134 °C. If the autoclave tape indicated that the pressure cooker did not operate in the specified temperature interval the use of pressure cooker might have been useless. Boiling water would be as effective as a pressure cooker reaching low temperatures. The result from the autoclave tape indicates that a favourable temperature is reached and the work could progress (See Figure 8 and 9). Autoclave tape is easy to find in Europe and one need only to use around 5 centimetre pieces, and an autoclave tape roll is usually around 50 meter. If the participants would travel to Mozambique, autoclave tape would have been bought in Europe and brought to Mozambique. It would be used in the beginning when purchasing the pressure cooker to examine the temperature interval the pressure cooker operates in.

#### **5.4.3 Biological indicator**

The best indicator would have been a biological indicator. Biological indicators contain bacterial spores that will indicate if the spores were eliminated in a sterilization cycle. If the spores were terminated that means that the objects being sterilized have been thoroughly sterilized. As stated before a biological test could not be made because of COVID-19. That does not eliminate the possibility to use a biological indicator. In the interview conducted by Olofsson, the nurse indicated that a certain indicator was used. That indicator would be thrown in the water that the birth kits were being sterilised in and when the indicator changed color that meant the birth kits

have been sterilised and they can be used. The nurse did not state or might have not known what type of indicator it is but said that it indicated the sterilization of the birth kits. That is why it is speculated that the indicators used in Linga Linga are biological indicators that could also be used when using the pressure cooker. Sadly, it can only be speculated if the indicators could be used and if they would work, as there is not much information about them and there is no opportunity to try it.

## 5.5 Prototype

The pressure cooker worked well when sterilising small instruments, according to the chemical indicators and visual appearance. According to the pressure cooker display, the inner chamber reached the desired temperature, time and pressure. It is believed that the pressure cooker might kill spores and bacteria, but because a biological indicator could not be made nor used, it cannot be confirmed if the pressure cooker sterilise.

The pressure cooker used had over 9 functions but few of the functions were not used, and some that were used did not work. Only three programs worked, "Porridge/Soup", "Meat/Chicken" and "Bean/Tendon" (See Table 3). These were the programs that reached a temperature of 130 °C and a pressure at around 100000 pascals. They had a time minimum limit of 30 min thus making them the most optimal for sterilization (See Table 4).

A metal spoon, inside a sterilisation pouch and sealed with autoclave tape, was put inside the pressure cooker. A cycle was put on using the data gathered from earlier experiments (See Table 4 and 3). The cycle was on 30 minutes and the program chosen was "Porridge/Soup" on the pressure "HIGH". The reason for doing this is to try the pressure cooker with a metal object and not only water and autoclave tape. The spoon inside the pouch was examined for any damages, to assure a safe use of the autoclave. The pouch was not broken nor was the pouch. The autoclave tape had also developed black stripes indicating that the temperature of 121 °C or higher was reached (See Figure 9). Thus, the conclusion was made that object can be put inside the pressure cooker, without the object or the pressure cooker getting damaged.

### 5.5.1 Indicators

The manometer did not work, the only source about the pressure of the pressure cooker was the manual. The desired pressure is between 100 kPa and 200 kPa through a regular autoclave cycle. It is believed that the pressure cooker reached a pressure of 100 kPa, but it is not known for how long it maintained that pressure. If the manometer worked one could have timed for how long it stays at a certain pressure, but also get a more accurate reading of the pressure.

The temperature had an accurate reading as it was displayed on the pressure cooker display. This indicates that pressure cooker reached a pressure of 100 kPa because according to the ideal gas law a high temperature leads to a high pressure if the volume is unchanged. With an accurate temperature displayed at 126 °C and the autoclave tape stripes turned black it can be guaranteed that the desired temperature of 121 °C or higher (See Figure 8 and 9).

### **5.5.2 Recreation of the sterilization method in Linga Linga**

The possibility of finding a pressure cooker with the same type of settings are slim. That is why it is recommended to get both a chemical and biological indicator to try out the programs. It is advised to try out the programs with the lowest time minimum and that caters to a type of meat. The reason for that being meat usually need higher temperatures and higher pressure to cook evenly and fast, thus the conclusion of any type of pressure cooker with a meat program might work.

For the people in Linga Linga, it might be hard to get the same chemical indicators used in this experiment, but according to the interview with the health worker, they had an indicator that they threw in the boiling water. It seems that the indicator turns a different color when the water reaches a certain (unknown) temperature. The same indicator can be put inside a pressure cooker to indicate if a certain temperature is reached. This speculation about how a pressure cooker and indicators might work highlights the differences between how healthcare, especially sterilization, is like in an industrialized country compared to a developed country.

First, finding credible sources for health care and sterilization was easy and the guidelines for sterilization were written and reviewed by a relevant authority. Compared with that, there was almost no acceptable information or guidelines about sterilization for the people in Mozambique nor in the neighbor countries. The only sources that could be found were healthcare workers.

Second, the amount of test and use of indicators that are available in Europe compared to Mozambique. For example, the Bowie-Dick test, biological indicators and autoclave tape. These tests are widely and commercially available all around Europe. It is recommended by the Swedish healthcare authority to for example use the Bowie-Dick test frequently. Because not much information about healthcare in Mozambique could be found, it is believed that they might not test as regularly as in Europe. It is also speculated that an individual might not have access to these indicators, the reason for that being that for this thesis most indicators were found online and bought online, compared to that not much is shipped to Mozambique.

Last, the quality of products. In Europe to be able to sell a product or service, it has to meet some requirements, get controlled and if it passes the control

and requirements it will get an EU-label that ensures the quality. The same type of control could not be found in Africa or in Mozambique, thus the quality of the product may not be up to par.

To summarize, the use of the pressure cooker as an autoclave can not be determined. According to the chemical and mechanical indicators the pressure cooker reached the desired temperature of 121 °C and a pressure of 100 kPa, but a biological indicator could not be made thus it could not be determined if the object inside the pressure cooker will be sterilized. Theoretically, it should give the same results if used in Mozambique, but that cannot be insured since the quality, use and range of pressure cooker might differ slightly or a lot compared to the one used, made and bought in Europe.

### **5.5.3 Sustainability**

If the introduced sterilization technique is tested with a biological indicator and succeed, it could be implemented in Linga Linga and use the electricity generated by the sun-panels that the students David Lindqvist and Hampus Nilsson made for their Master Thesis with Project Vita [26].

## **5.6 Sources of error**

It is discussed how the method could be improved to give better results. It should be stated that mechanical and chemical indicator can in no way indicate if an object is safely sterilised. However, they helped find systematic errors in the system and examine the instruments parameters to ensure a safe usage of the instrument. The result of these indicators only showed if the pressure cooker reached the desired parameters, for example temperature.

### **5.6.1 Workplace**

For the unforeseen reasons of a pandemic, the research had to be performed in a commercial kitchen, at the home of the authors of this thesis. All the results only applies for pressure cookers and indicators from Europe and done in Sweden, thus results from Mozambique can only be speculated. Not being able to travel to Mozambique made it harder to control and conduct the interviews. Because of COVID-19 only one person could be interviewed which lead to a unilateral idea about the sterilization in Linga Linga. This could have been avoided if more interviews were conducted and if the authors of this thesis could have overseen the interviews on Skype or Zoom (could not be done because of bad internet connections).

With the method, an improvement that could be made is trying the experiment in a controlled environment. Once again, because of COVID-19 Universities and laboratories were closed, thus the experiments had to be done in a kitchen, at the home of the participants of this report. This could lead to

others touching the pressure cooker and it could change the time or pressure, the pressure cooker could have been contaminated or destroyed, but it is not believed to have happened.

### 5.6.2 Material

The pressure cooker bought was pre-used. According to the seller the pressure cooker was only used once, meaning that the pressure cooker should be as good as new. There was no visible damage to the vessel or lid and it worked correctly all the time. However, this does not eliminate the doubt that the pressure cooker could have been used several times or got damaged. It would be most favorable if a new pressure cooker was used to get accurate results. A new pressure cooker is expensive thus a cheaper, pre-owned pressure cooker was favored.

A problem that arose in the beginning, was the use of a manometer and the measurement of the pressure inside the pressure cooker. The manometer did not show any accurate readings when the pressure cooker was on, it showed that the pressure was 0 psi (0 Pa). The pressure cooker did not display the pressure, the only reliable sources for the pressure was the manual, no exact measure of the pressure could be made. There are several reasons for the manometer not working. Firstly, it might not have been installed correctly, since no sources for the installment of a manometer on a pressure cooker could be found. Secondly, the manometer itself might have been broken, a new one maybe would have shown a different measure. Lastly, a manometer might not have been needed. It would be optimal to buy a pressure cooker that showed the pressure on display or with a manometer already installed.

The use of a pressure cooker was supposed to cater to the needs of the people of Linga Linga, for example be electrical and portable. Only material that could be acquired in Linga Linga would be used. Because the experiments were done in Sweden the material acquired, for example sterilization pouches, were easy to find and buy. The same assumption can not be made about the acquisition of the sterilization pouches in Mozambique. An alternative could not be found but it is believed that the birth kits they get in Linga Linga are already in sterilization pouches and that they could find sterilization pouches in big cities or get them from hospitals.

While some material were easy to find and get, some were impossible. A biological indicator was to be made and used, using the bacteria *Geobacillus stearothermophilus* and *Bacillus atrophaeus*. The indicator could not be made because an individual can not buy bacteria, and the bacteria need a special incubator to grow the colonies, because of COVID-19, laboratories were closed, thus no biological indicator could be made. In Mozambique s biological indicator would not have been made because of the inaccessibility to material and laboratories, but the healthcare worker mentioned an indicator they use to



check if the birth kits had been sterilised. Since no more information could be found it is only speculated that they are biological indicators that could also be used in a pressure cooker to assure sterility.

### **5.6.3 User**

The use of an electrical pressure cooker might be a foreign thing for the health workers in Linga Linga. On one hand, a manual was made to make it easier to understand, build and use a modified pressure cooker to sterilise medical equipment. On the other hand, an oral and visual explanation will be needed to assure that the users can use the pressure cooker safely and comfortably. If it is possible this can be done through Skype or Zoom or, if the travel-ban is lifted, in Linga Linga.



## 6 Conclusion

In healthcare facilities, sterilization of medical equipment can be achieved by heat (moist or dry), chemicals (gas or liquid) or ultraviolet light. Moist heat sterilization was considered to be the most effective method of sterilization in low-resource settings, such as the maternity clinic in Linga Linga, because it is time- and cost-efficient, safe and effective compared to the above-mentioned methods.

Steam sterilization is accomplished with an autoclave and utilizes the same parameters as a pressure cooker. As confirmed with mechanical and chemical indicators, the temperature range of 121-130°C can be achieved in a pressure cooker when set up for 30 minutes. Theoretically, this means that sterilization can be achieved with a pressure cooker, thus it can work as a smaller autoclave. However, this could not be confirmed with biological indicators due to the restrictions that has come with the global pandemic.

Despite the fact that this project could not confirm, with experiments, that a pressure cooker can work as an autoclave, a manual that describes the process of building an autoclave from a pressure cooker has been written so that the alternative methods be recreated by the clinical staff in Linga. When confirmed with a biological indicator, this method could be implemented in the maternity clinic of Linga Linga.



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## Appendix 1: Instruction manual on how to build and operate the autoclave



Figure 10

## Preparation

### How to set up the autoclave

1. Remove the stopcock whistle/ valve from the vent tube fitted at the lid.
2. Twist the lid of the pressure cooker anticlockwise and lift the lid.
3. Place the grill inside of the pressure cooker.
4. Pour water inside of the pressure cooker, just enough to reach the grill.

### How to prepare the instruments

5. Clean all instruments with soap and water.
6. Insert each instrument in a sterilization pouch or in any of the alternatives that is suggested under "Material".
7. Seal the pouches with autoclave tape.
8. Place the instruments in the stainless steel drum or in any of the alternatives that is suggested under "Material".

## How to Test the Autoclave

1. Cut out four 5-10 cm long strips of autoclave-tape and place three on the side of the inner container, with about 5 cm spacing between the strips.
2. Put on the lid, press it down and turn it clockwise until it does not turn anymore.
3. Put and press down the Stopcock whistle/valve on the vent tube on the lid.
4. Turn on the power.
5. Let the process go on for 30 minutes, without any load on a program that reaches a temperature of at least 121°C.
6. Check that there is no leakage in the pressure cooker, by observing any changes throughout the program.
7. Turn off the power and lift or pull out the Stopcock whistle/valve of the vent tube with a piece of cloth.
8. Let all steam leave the autoclave. If there is a pressure gauge installed, make sure it is at Zero lb psi.

Figure 11

9. Open the autoclave lid by twisting it anticlockwise and lift the lid off the base chamber.
10. Check if the autoclave-tape has changed color.
11. Repeat the whole process with different programs until the autoclave-tape changes color.

### How to Use the Autoclave

#### How to start the sterilization process

1. Place the drum with the material inside of the pressure cooker, over the grill.
2. Put on the lid, press it down and turn it clockwise until it does not turn anymore.
3. Put and press down the Stopcock whistle/valve on the vent tube on the lid.
4. Turn on the power.

#### How to set up the program

5. Let the process go on for 30 minutes on a program that has been tested according to the steps under "How to Test the Autoclave".

#### How to end the sterilization

6. Turn off the power and lift or pull out the Stopcock whistle/valve of the vent tube with a piece of cloth.
7. Let all steam leave the autoclave. If there is a pressure gauge installed, make sure it is at Zero lb psi.
8. Open the autoclave lid by twisting it anticlockwise and lift the lid off the base chamber.
9. Remove the drum with the instruments from the autoclave and preserve it in a safe place.
10. Remove all the water from the chamber and close the autoclave by putting the lid on it clockwise.
11. Put the stopcock whistle/valve back on the vent tube for next sterilization.

Figure 12

### Care and Maintenance

- Test the autoclave daily.
- Disconnect the autoclave from the main power supply before cleaning.
- Clean & dry the unit after a day use.
- Weekly clean both interior and exterior with soap and warm water, ensuring the electrical parts are kept dry.

### Warning

- Do not operate the stericlave without water. Avoid Using Hard Water in the unit.
- Do not put any extra weight on the stopcock.
- Close the stericlave lid properly never try to open it by force without first releasing the steam.

### Disclaimer

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Figure 13

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