Fast Towel Disinfecting Cabinet

Team 25 -- Yujie Wang and Christopher Willenborg and Harsh Agrawal
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TA: Kyle Michal

1 Introduction

1.1 Objective

With society progressing rapidly, people have higher standards of living. The well-being of the population is imperative for any country. This awakening of rising concerns over personal health has led to a huge increase in the global personal hygiene market [1]. However, bath towels are often overlooked by people for how dirty they are. Sadly, more often than not, people wash their towels about two or three times a month, leaving their damp, warm towels to dry in dark, poorly ventilated bathrooms between uses. This creates a perfect environment for bacteria to thrive into a decent-sized colony on the towels. Although many of the bacteria are harmless, there is still a small portion that makes people sick. A study conducted by Charle Gerba, a microbiologist at the University of Arizona, suggests that nearly 90% of bathroom towels were contaminated with coliform bacteria and about 14% carried E.coli [2].

We would like to solve this problem by building a wall-mounted towel disinfecting and drying cabinet that uses UVC light to kill all the bacteria and dry it faster than air drying to prevent any bacteria to thrive on the towel.

1.2 Background

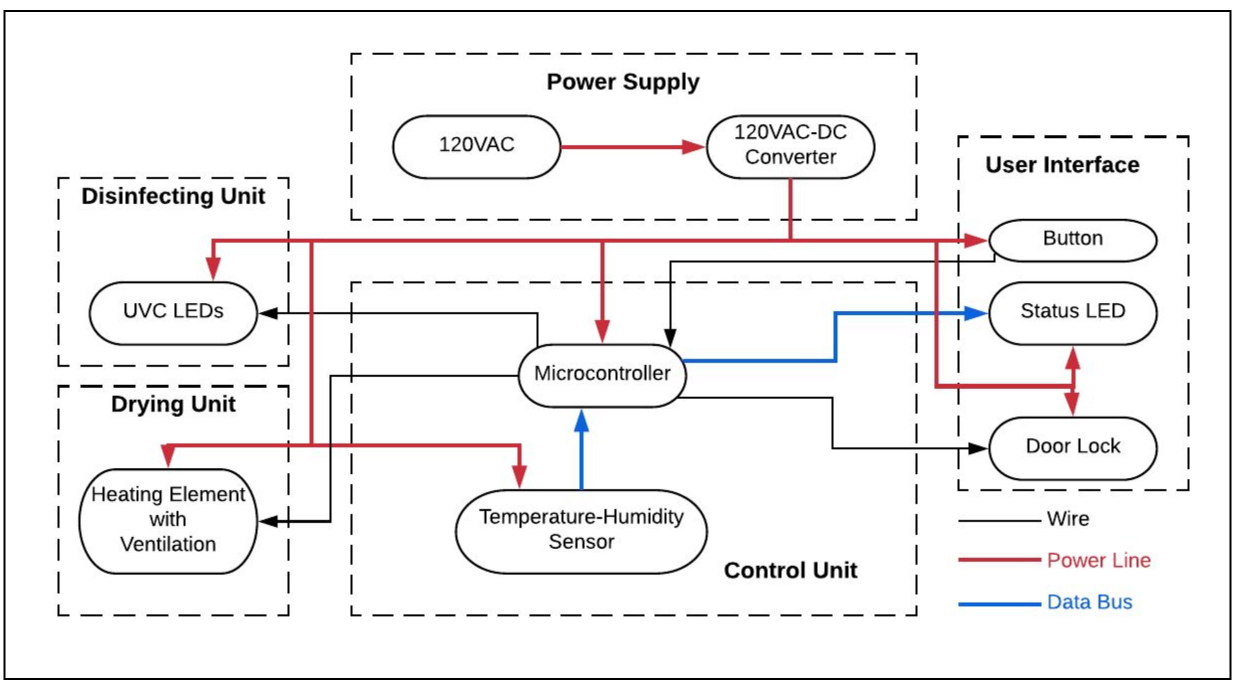
The recommended usage of a towel is two to three days [3], but from speaking with our friends and acquaintances we have determined that the average person only cleans their towel once every 10-15 days. We would like to increase the personal health of people, by disinfecting one of the least likely places people expect to contain disease-causing bacteria.

Currently, no products exist in the market to solve this problem. There are heated towel racks available that can dry your towel faster than air drying but that does not prevent bacteria to grow on the towel. There are hot towel sterilization cabinets that use ozone or UV-C light intended to be used in salons and spas to keep cleaned face or hand towels damp, warm and bacteria-free. Our product should be a sleek disinfecting and drying wall-mounted cabinet to keep bath towels clean and dry between uses. This cabinet should neutralize a substantial portion of the E. coli determined to be present on the towel.

1.3 High-level requirements

- The cabinet should be designed such that the UVC light completely covers the towel as to kill bacteria.
- The cabinet should dry a wet towel, and the humidity in the cabinet should be at or below 50% upon completion.
- We will implement a self-locking mechanism to keep the door locked during the disinfecting-drying process to avoid shining UVC light on the user.

2 Design



We will be using four UVC lights in our cabinet. To achieve full coverage, we will put two in the door of the cabinet and two against the back wall. We predict to have the front and back UVC lights each 8” away from the towel. There will be a rod at the top with moveable clips to hang towel of any size inside the cabinet. We will implement a heating element and fan into the bottom of our cabinet to successfully convection dry our towel and decrease humidity. There will be vents at the top of the cabinet for air to flow in/out for the fan. There will be a door lock to keep the door closed.

2.1 Power Supply

A power supply is needed to take 120VAC from the wall outlet and regulate it to 5-12V DC for the microcontroller and all other components.

2.1.1 120VAC

This cabinet will be powered by a 120VAC by connecting it to a wall outlet.

Requirement: We need rated cable that can take the power from the wall outlet and deliver it to our cabinet. 12 or 14 AWG should be a sufficiently sized cable.

2.1.2 120VAC - DC converter

An AC-DC converter will convert the 120VAC to DC to power the microcontroller, sensors and all other components.

Requirement: The converter should take the 120VAC and step it down into a range of 5VDC to 12VDC with a voltage tolerance of 5% required by the components.

2.2 Control Unit

The control unit will control every operation of the device, specifically: accepting user input from the button, controlling the UVC LEDs and drying unit, maintaining the desired temperature based on readings from the sensors, displaying progress and other information on the LCD display.

2.2.1 Microcontroller

The microcontroller carries out all of the operations. The microcontroller should have enough GPIO pins to support all of our sensors and signals. We estimate one or two temperature-humidity sensors. All of the UVC lights will use the same signal, but we might need to create a separate signal for the heating element and fan depending on just how long it takes to dry the towel. We should reserve a few extra GPIO pins in the event that we need more sensors or wish to implement extra features and the user interface.

Requirements: Taking this all into account we will need in the range of 10 and 15 GPIO pins.
Note: Other more specific requirements for the microcontroller will be available once we are further into the design process.

2.2.2 Temperature-Humidity Sensor

The Temperature-Humidity sensor, a DHT22, will provide temperature and humidity measurements of the air inside the cabinet to allow the control unit to maintain a set temperature inside the cabinet and display the measurements on the user interface.

Requirement 1: The temperature-humidity sensor must work in 3.3-5V ± 5% with 2.5mA maximum current.
Requirement 2: Should read temperature with a ±1℃ accuracy and humidity with a ±5% accuracy.

2.3 Disinfecting Unit

The disinfecting unit consists of the four UVC LEDs required to disinfect the towel. This unit will be controlled by the microcontroller, specifically, it will turn the UVC LEDs on for a set amount of time to achieve the desired disinfection.

2.3.1 UVC LEDs

The UVC LEDs will be mounted on the front and back of the cabinet in a way that they cover the entire surface area of the towel. They will shine UVC light on the towel, killing all the bacteria, specifically E. Coli.

Requirement 1: The LED shines a light of wavelength 280 ±5 nm with a viewing angle of 130° with a tolerance of 10°.
Requirement 2: The LED should work at 7 ±*1 V with 100mA nominal current.*

2.4 Drying Unit

The drying unit consists of a heating element, fan and vents to dry the towel.

2.4.1 Heating Element with Ventilation

The heating element should be powerful enough to support successful convection without producing so much heat that it would pose a substantial fire threat.

Requirements: Tentatively, a 100W 12V Fan Heater that maintains a constant temperature.

2.5 User Interface

The user interface consists of three elements: a button for the user to trigger a disinfecting-drying cycle, a status LED to show progress, and a door lock to prevent shining UVC light on the user.

2.5.1 Button

A button on the outside of the cabinet will allow the user to trigger a disinfecting-drying cycle.

Requirements: A robust easy-to-use push button.

2.5.2 Status LED

A status LED to show the three modes of operation: disinfecting (blue), drying (red), done (green).

Requirements: A RGB LED that works at 1.8 ±0.2V for Red and 3.2 ±0.2V for Green and Blue with 20mA current.

2.5.3 Door Lock

A door lock is required to keep the door locked during the disinfecting-drying cycle. The door will lock at the start of a cycle when the button is pressed and open when the cycle is complete.

Requirements: A door lock that can be controlled by a microcontroller, tentatively a solenoid lock that works at 11 ±1 VDC drawing maximum 650mA current.

2.6 Risk Analysis

We suspect that quantifying the amount of bacteria killed will be the biggest challenge to the success of our project. This will be challenging because we are not well experienced in this field. The current plan is to take petri dish samples or contact someone on campus to take samples for us. The petri dish method takes approximately a week to see results. There is a good chance that reserving a full week in advance to the deadline to take samples could be an issue. Another potential problem from taking the petri dish samples would be if we were to mess up the samples. There would be virtually no time to retake new samples in time for the deadline.

3 Ethics

There will most definitely be some safety concerns that we need to account for with our project. One of the first that comes to mind is the potential harm that can come from UVC light exposure. To mitigate this concern and abide by IEEE Code of Ethics, #1: “to hold paramount…” [4], the first step we will take is to implement a self-locking mechanism that will not allow users to open the door and expose themselves to UVC light when our cabinet during a towel cleaning cycle. The second step we will take is to inform the user of all potential hazards with using this product and explain how to avoid harming themselves complying with the IEEE Code of Ethics, #1: “to disclose promptly factors that might endanger the public” [1]. One way the user can be exposed to UVC light is if they intentionally leave the cabinet open and trigger a cycle. We haven’t incorporated a solution to this in our design but if we have extra time we might add a feature to only trigger a cycle if the door is closed.

We will need some sort of safe voltage regulation if we are to use the 120VAC from a wall plug. The hazards of using 120V in wet conditions are quite obvious when it comes to the potential of electrocution. We would need to safely step down the voltage to power the heating element, sensors, lights, and microcontroller.

The moisture that we expect to experience inside of our cabinet could be detrimental to any PCBs that we use. We currently plan on spraying the PCBs with a hydrophobic coat of sort to keep the water that accumulates on the surface from shorting any of our components. We would also like to incorporate some type of ventilation if we have spare time in an effort to keep moisture from accumulating on our components. Another way to combat this issue would be to keep the microcontroller in a enclosure inside the cabinet so that the moisture does not reach it.

Since our product is in the development phase and is more of a proof-of-concept design at this point, we conservatively claim that our project would kill most but not all bacteria. After formulating a method to test the effectiveness of our disinfection unit, we would report the achieved bacteria kill rate. This is the encouraged practice by the IEEE Code of Ethics, #3 “to be honest and realistic in stating claims...” [4].

We are incorporating a convection system, which means we will need a heater. The issue we expect the user could encounter with the heating system is potential fire hazards such as lighting up the towel on fire. We will design the system to maintain a safe temperature inside the cabinet to avoid the possibility of burning the towel. We would also purchase a fan with a guard to avoid any potential injury to the user if they intentionally put their hand in the fan.

We know that wires are not typically a safety concern, but due to the nature and size of our project, we will have wires spread all throughout our cabinet. We do not want the wires to be in the way of other components, so we plan on wrapping wires in a bunch against the wall.

References

[1] “Global Personal Hygiene Market: Overview,” Personal Hygiene Market. [Online]. Available: https://www.transparencymarketresearch.com/personal-hygiene-market.html. [Accessed: 07-Feb-2019].

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[3] TodayShow. (2017, May 16). How often should you wash bath towels? Retrieved February 7, 2019, from https://www.today.com/series/one-small-thing/how-often-should-you-wash-bath-towels-t111625

[4] IEEE Code of Ethics. (n.d.). Retrieved February 7, 2019, from https://www.ieee.org/about/corporate/governance/p7-8.html