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AUTOMATED RAPID IDENTIFICATION OF MYCOBACTERIUM TUBERCULOSIS STRAIN

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Abstract—TB is curable and preventable. TB prevalence among men was over 2 times as high as among women. Actual number of TB infected people is much greater than notified and this problem is due sheer lack of accessibility to test facilities. we aim to design a setup that can be carried to remote areas basically slums where TB care facilities are inaccessible which will identify the presence of a Mycobacterium tuberculosis strain from a swab sample. The result will lead to into urgent actions to be taken for the treatment of the patient. The whole process will be automated and fast enough to give results in just a couple of minutes.

Keywords- Mycobacterium Tuberculosis, carbolfuchsin, Arduino UNO Microcontroller

I. INTRODUCTION

Tuberculosis (TB) is a communicable disease that is a major cause of ill health, one of the top 10 causes of death worldwide and the leading cause of death from a single infectious agent (ranking above HIV/AIDS). TB is caused by the bacillus ***Mycob-acterium tuberculosis***, which is spread when people who are sick with TB expel bacteria into the air. The disease typically affects the lungs (pulmonary TB) but can also affect other sites (extra-pulmonary TB). TB can affect anyone anywhere, but most people who develop the disease are adults. TB treatment has averted more than 60 million deaths, although with access still falling short of universal health coverage (UHC), many millions have also missed out on diagnosis and care. This gap is due to a combination of underreporting of people diagnosed with TB and underdiagnosis (if people with TB cannot access health care or are not diagnosed when they do).

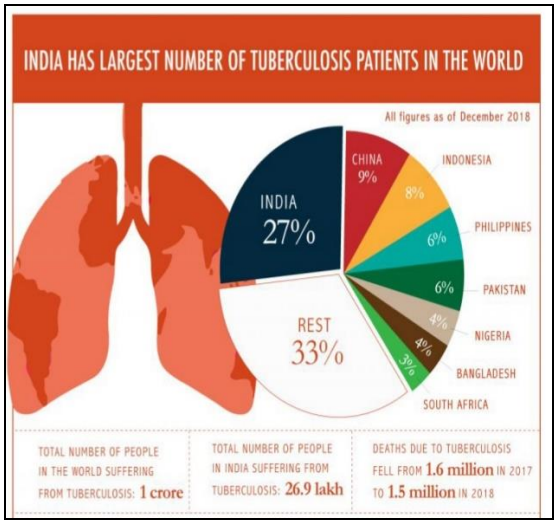

Fig 1-Trends of TB infection in India vs the global trends. [1]

High-level commitments have galvanized global, regional and national progress towards ending TB, but urgent and more ambitious investments and actions are required to put the world on track to reach targets and Early accurate diagnosis followed by prompt appropriate treatment is vital for ending TB.

Estimates of TB Burden (WHO 2019)	Number	Rate per 100,000 Population
Incidence of TB cases (includes HIV + TB)	2.640 million	193
Incidence (HIV+TB only)	71,000	5.2
Incidence (MDR/RR-TB)	124,000	9.1
Mortality (deaths) (excludes HIV+TB)	436,000	32
Mortality (deaths) (HIV+TB only)	9,500	0.69
Proportion of TB cases with MDR/RR-TB, 2019 New Cases/ Previously Treated Cases	2.8%/14%	

Fig-2: Estimates of TB burden (WHO 2019) [2]

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The table above shows the estimates of TB burden (according to WHO TB report 2019).
The rest of the paper is organized as follows. Our solution for issue has been proposed in section II, followed by the experimental apparatus, working and circuits are explained in section III. Unique value Proposition are presented in section IV. Concluding remarks are given in section V.

II. PROPOSED SOLUTION

The solution we have designed is a fast TB strain identification unit which is automated and can be carried to remote areas for executing TB care facilities where it is inaccessible and this is due to combination of underreporting of people diagnosed with TB and underdiagnosis (if people with TB cannot access health care or are not diagnosed when they do).
The basic ideas governing our setup include the use of various indicators for staining the swab sample like **carbolfuchsin, acid alcohol & methylene blue,** functioning of a **microcontroller (ARDUINO UNO) with different modules** for processing the image captured by the digital microscope, controlling the conveyor belt on which the slide moves and controlling the stoppers of the bottles containing different indicators.

III. DESIGN & WORKING

Apparatus/Layout

a. The whole setup consists of a cuboidal transparent fiber box like structure of 120 cm length and 60cm height and breadth with display unit, a digital microscope with a camera, inlet and outlet slots attached.
b. The inlet and outlet slots are connected to a conveyor belt at 10cm height from base on which the slide containing the swab sample moves according to the instructions from the microcontroller.
c. 20cm from top, a bar is fixed onto which the three bottles each of 7 cm containing indicators are fixed.
d. The primary stain bottle i.e., Carbolfuchsin is fixed at 10 cm from the inlet side. And a heat flame is set below the conveyor belt at 10 cm away from the first stain bottle.
e. 5cm right from the center (which is 60cm from inlet) , acid alcohol bottle is fixed and 5cm left from the center i.e. 55cm from the outlet slot methylene blue bottle is fixed.
f. There is also a water sprinkler attached on the conveyor belt to remove the excess stain out through the holes in the belt.
g. The digital microscope is placed vertically at the center of the setup 60cm from either side to allow the camera fixed to it to capture highly magnified images of the sample after all the process gets completed.

Fig-3 shows the layout of our setup.

Circuits

a. The camera is connected to the ocular lens of the microscope. It captures the magnified image and through the microcontroller gets stored in the sd-card module which is then displayed using an LCD monitor.[3]
b. The conveyor belt has 2 dc motors and stoppers have 3 servo motors attached to control their operation using the microcontroller [4].

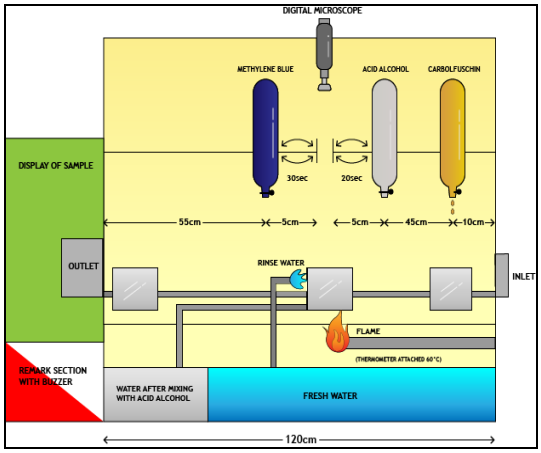


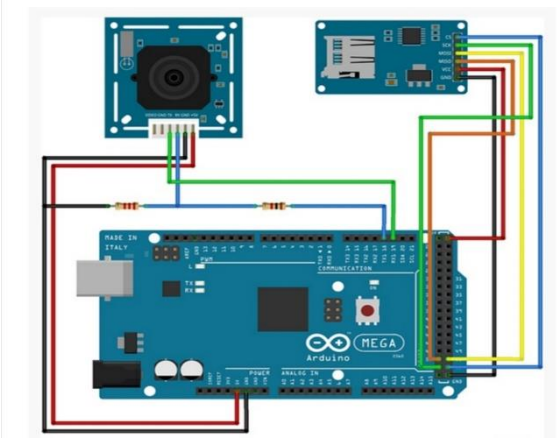
Fig-3: Layout of our setup

c. A color sensor module is fixed near the ocular lens to sense the red color and is hence attached to buzzer to give a signal.

Fig-4 shows the microcontroller circuit with its modules.

VC0706 Serial Camera

SD Card Module



ARDUINO UNO Microcontroller

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Fig-4: Microcontroller circuit

Working:

STEP 1:
At first the swap sample of the person to be tested is taken and placed in a glass slide. The slide is then placed into the inlet slot of the device, which then gets onto the conveyor belt (total length 120cm) which slides based on the microcontroller's instructions given during design of the setup.

STEP 2:
When it enters the unit, first a primary stain (2-4 drops) of carbolfuchsin is added onto it at 10cm from inlet and it stays still for around 30 seconds. The belt is then activated and the slide moves 10cm to the heat flame point. Heat is applied and it stays there for 10 seconds and then moves to the centre of the belt (60 cm from inlet).

STEP 3:
It stays there for 30 seconds and then moves back 5cm and 3-5 drops of acid alcohol is added to decolorize it. It stays there for 20 seconds. It then moves forward 10cm to the methylene blue unit which is added 2-3 drops. The slide stays still for 20 seconds and returns back to the centre i.e. 5cm back.

STEP 4:
The water sprinkler rinses the slide to remove excess stains and then the digital microscope on instructions of the controller takes highly magnified images and sends it to the controller for image processing.

STEP 5:
The micro-controller displays it on the display monitor. There is also a buzzer attached which gives a danger signal if the images from the microscope detect red strains left out after the whole process.

STEP 6:
The opening and closing of the stoppers of the bottles containing the indicators is controlled by the microcontroller.

IV. UNIQUE VALUE PROPOSITION

Our innovative solution to the problem exhibits many unique features like:

a. The whole operation is automated, the instructions are programmed in the microcontroller unit with different operation modules and libraries imported into it. It solely controls the operation of the device that includes controlling the stoppers staining of the swab sample, operating the conveyor belt and processing the magnified image captured by the camera attached to the digital microscope.
b. Minimal number of medical staff presence is required just to take the swab samples from the people being testing and inserting the slide to the inlet slot, then giving the report after the device analyzes the presence of M. tb strain in the swab sample.
c. Our product has a large operational area to be operated in large slums like SALIA SAHI of Bhubaneswar.
d. It is fairly a light, portable device with comparatively low price of production compared to other RT-PCR kits and is expected to have a high market size.

V. CONCLUSION

a. After prior testing in official laboratories our setup is expected to give rapid identification results of the bacteria strains in swab tests and to the extent possible efficacy.
b. It is expected to have a large market size after stage wise implementation on target customers.
c. In long run, the product will act as a great contributor in the field of TB care by allowing its access to remote areas.
d. The implementation of our product is expected to set a new milestone in the process of ***"Stop TB movement"***

VI. REFERENCES:

1. WHO Global TB report 2019
2. WHO Global TB report
3. https://www.arduino.cc/en/Tutorial/BuiltInExamples
4. https://www.circuito.io/blog/arduino-code/