Development of Low Cost Diagnostic Devices For Monitoring Public Health and Disease Prevention

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ABSTRACT

The development of low-cost point-of-care diagnostic technologies might potentially save millions of lives and protect the population from a wide range of diseases. By providing safety for everyone, these gadgets can not only reduce the cost of healthcare but also raise living standards. These easily constructed devices hold great promise for underdeveloped countries, where a greater need for affordable, reliable instruments is present due to the widespread presence of diseases. In order to address the primary public health concern and build low-cost devices for disease prevention and public health monitoring, it is suggested in this work that material engineering be used at a synergistic interface. To ensure that food and water are safe for human consumption, it is crucial to monitor them for the organism that causes infectious diseases. Contaminated water can cause a number of infectious diseases, with underdeveloped countries having the greatest rates of food and waterborne illness cases. Assessing the quality of water and quickly identifying harmful bacteria continue to be difficult tasks in the fight to protect public health and stop bioterrorism.

1. Introduction

India is the world's largest democracy and a nation whose remarkable economic growth is propelling it forward in the international arena. From 1995 to 2016, India's population increased by 250 million, while the percentage of the population living below the poverty line decreased by half. As wealth rises, so does the threat of disease, with lifestyle diseases accounting for half of all fatalities in 2016 [1]. By 2020, the healthcare sector, which reached $81.3 billion in 2013, is predicted to have risen to 17%. As a result, it becomes quite difficult to provide healthcare facilities in rural areas [3]. India's healthcare system is beset with numerous issues. The US spends 125 times more than China, which spends 5.6 times more, but government spending as a percentage of GDP and per capita health expenditures are among the lowest in the world [2]. India's current infrastructure is insufficient to contain epidemics of newly developing diseases. Furthermore, whereas 67% of people reside in rural areas, 75% of qualified doctors practise in urban areas, 23% in semi-urban areas, and 2% in rural areas. Furthermore, the great majority of people in the northeast and north-east reside in hilly regions, with some of them also living on isolated islands, making access to healthcare impossible in these far-off places [5]. In response to these difficulties, the Indian government has pledged to allow 100% foreign direct investment in the healthcare sector by the end of 2017 and to raise healthcare spending from 1.4% to 2.5% of GDP [11]. To now, medical equipment account for 75% of India's imports, with the US supplying 30% of them. Compared to rich countries, emerging countries face distinct healthcare issues [14]. The mismatch between the design of the technologies and their execution in light of the realities of the healthcare infrastructure in developing countries is the result of imports from rich countries. The development of indigenous technologies is necessary in order to address India's healthcare concerns. In a contribution to this the thesis aims at developing new platforms that assist biomedical engineers and public health workers to detect and diagnose bioanalytes in efficient way possible. In this case, the introduction is examined in section 1 of the article while the overview of modern detection technique is discussed in section 2. Section 3 explains the application of smart phone based diagnostics system, Section 4 shows the discussed the proposed diagnostic model, and Section 5 concludes up the project.

Modern Detection Techniques

The colorimetric assay, created by Mirkin's group in 1996, served as the foundation for the development of contemporary nanomaterial-based simple detection techniques. They achieved this by explaining how the size-dependent optical characteristics of gold nanoparticles can be used to selectively identify analytes using biomolecular recognition. Since then, advancements in the fields of biotechnology, nanotechnology, and microelectronics have transformed these gadgets into much more portable, affordable, and quick machines that can identify various diseases in short amounts of time. Despite being relatively new to the diagnostic device family, these detection methods offer simple, efficient, and affordable alternatives for both qualitative and quantitative analyte detection by employing nanoparticles as an amplification component [4].

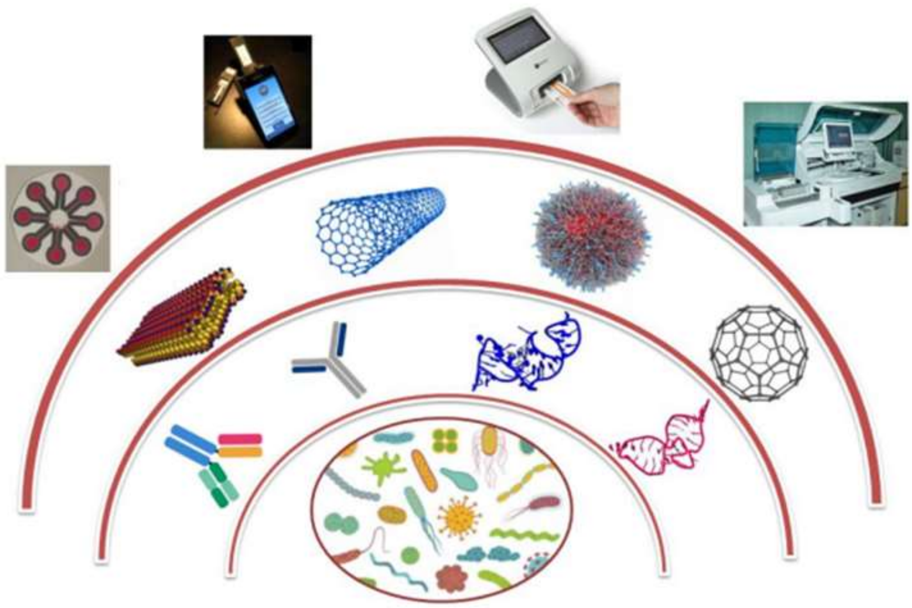

Figure 1. Basic elements of a diagnostic device in a core diagram

Recent demands for quick and inexpensive devices demonstrate that they are a viable alternative to traditional culturing and biochemical procedures for detection [12]. These detection methods are basically composed of four parts. The first type of sample is biological, and it comprises food, animal, environmental, and human (urine, blood, saliva, stool, etc.) samples. A recognition element that attaches particularly to its analytes comes in second. Antibodies, aptamers, drugs, molecularly imprinted polymers, and any other chemical or biological component with particular binding affinities are a few examples of these recognition elements. The signal amplification unit is the third component. Traditionally, this unit has been made up of enzymes or other molecules that are catalytically active, but efforts are currently being made to replace these with considerably more sensitive nanostructures. The readout that is produced depends on the type of amplification process used and can be either optical, electrochemical, or mass based. The user readout is the fourth component. This device displays signals that have been boosted for the user or doctor. This device used to be made up of an intricate instrument display, but with to technological advancements, low-cost substrates like paper, Arduino, and smartphones are now used. The fundamental parts of a contemporary diagnostic gadget are shown in Figure 1.

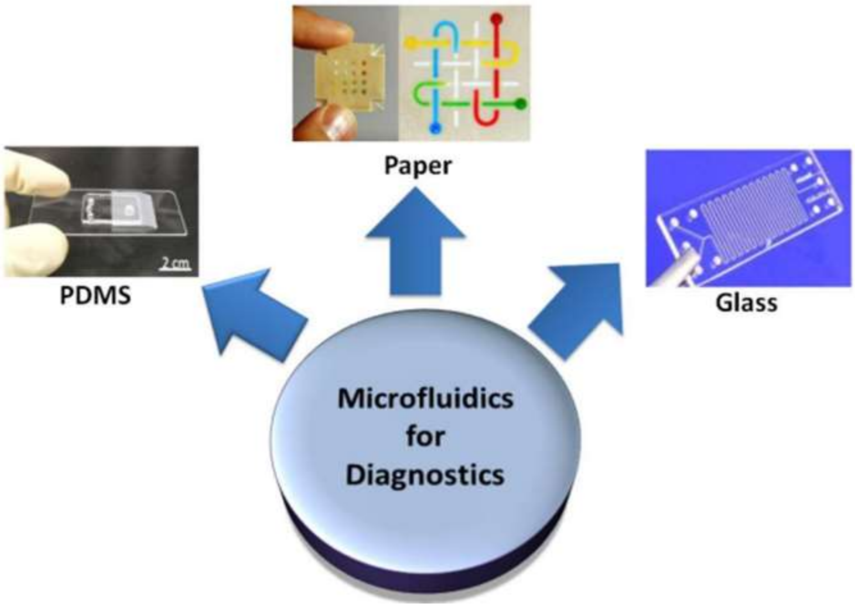

Figure 2. Illustration of various materials used for developing microfluidics based diagnostic devices

When an analyte is detected, optical sensors record changes in fluorescence, luminescence, absorbance, and reflectance. Numerous optical bioassays using light from the ultraviolet, visible, and near-infrared spectrums are documented in the literature for the detection of chemical and biological analytes. One of the main advantages of optical techniques over other approaches is their easily readable signal output. Labelled and label-free bioassays can both produce optical signal readouts. A receptor element is labelled in a labelled bioassay with an enzyme or nanomaterial that, when the proper substrate is added, produces an optical signal (colorimetric, fluorescence, or luminescence). The interaction between the analyte and the transducer, or nanomaterial, is what generates the signal in label-free bioassays. Colorimetric and fluorescence-based methods are the most widely used for the detection and quantification of biological substances among all the optical signal readout techniques. Fluorescence-based methods make use of molecules known as fluorophores, which have an electrical structure that permits light to be excited and emitted in the visible and near-infrared spectrums. These molecules can be utilised to detect analytes through binding events when coupled with a particular receptor probe. Optical filters are a simple way to separate and gather fluorescence signals, as are photodiodes. Distinctive from traditional fluorescence-based immunoassays Assays based on Forster resonance energy transfer are likewise becoming more popular in the study and analytical fields [6].

Smart Phone Based Detection Systems

Point of care systems are becoming more prevalent in the diagnostic paradigm as a result of the rapid improvements in technology. In both high- and low-income economies, smartphones are increasingly becoming commonplace [13]. Smart phones can be used to give people access to medical diagnostics in many places across the world where advanced technology are either unavailable or not yet implemented. In order to provide healthcare treatments in remote locations, the developing field of mobile health makes use of mobile devices and communication [8]. More than 94% of people on the planet use mobile phones, with 70% of those who use smartphones coming from developing nations. The market for smartphones has grown significantly as a result of the remarkable rise, as well as new features and lower costs. Smartphones contain an amazing amount of sensors and computer-like software that allows them to command and operate medical equipment. The processing and storing of diagnostic results is made easier by the powerful processors and memory that are integrated in. Additionally, smartphones have the ability to transmit data via USB and GSM, which enables specialists in consulting to communicate with a central laboratory and a remote test region. In developing nations, where smartphone-based diagnostics offer a more affordable option than expensive instrumentation, this kind of interface is highly valued. To precisely address the diagnostic problems of RLS, a variety of smartphone-based gadgets have been created in recent years. For instance, a plug-and-play blood pressure monitoring gadget based on a smartphone has already been introduced to the market to replace traditional stethoscopes and sphygmomanometers. Numerous more gadgets featuring features like heart rate monitoring and calorie counting are offered in the market to provide individualised medical treatment [7]. While several in-built sensing technologies are included in smartphones, the main sensing functions utilised in point-of-care devices are restricted to the camera and image processing algorithms. Nonetheless, a range of sensors might be included as smartphone accessories to boost the range and precision needed for diagnostics. Figure 3 shows several instances of diagnostic devices based on smartphones.

Figure 3.Adaptation of many commercially available smart phone based diagnostic devices for representation of application of smart phone in medical purposes.

With the introduction of medical applications in non-medical devices, which people from non-technical backgrounds are already familiar with, smartphone technology offers great opportunities for improving public health by removing barriers that millions of people face when trying to access sophisticated medical laboratories.

Arduino Based Colorimetric Device For Disease Detection

Simple and quick testing is essential for the efficient avoidance of fatal diseases when it comes to bacterial detection [9]. By saving money, these tests could lessen the pressure on public agencies as well as the cost of pointless therapies. Because of their integrated interfaces and low cost, open source microelectronics have shown to be an interestingly beneficial tool in analytical chemistry [15]. Potable instrumentation and microcontrollers make a convenient combination for data collection and analysis [10]. In diagnostics, low-cost micro-controlling platforms like Arduino chip sets are becoming more and more crucial.

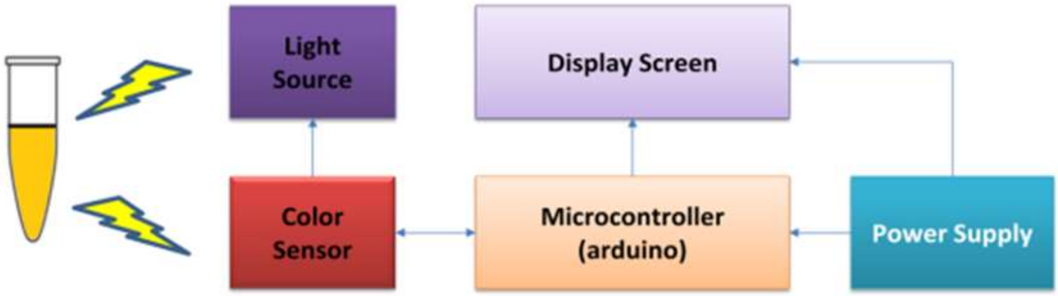

Figure 4.Schematic depiction of various components of an arduino based colorimetric device

A microcontroller board plus an environment for developing programmes on board make up the open-source Arduino platform. The most common languages used to write programmes are C and C++. Atmel is the company that creates Arduino micro-controllers, which are single-chip microprocessors. Their data handling and control capabilities enable the quick development of systems without the need for further parts. The Arduino IDE is the name of the Arduino programming environment. Users can draft programmes with it, which they can then put onto microcontrollers. Processing is the language used by Arduino that is user-friendly. The IDE compiles and translates the written programme into assembly language. The programme is uploaded to the CPU by the IDE upon translation. Additionally, the integrated code in the IDE verifies written code prior to compilation. With the right sensors, Arduino components can be used with ease in a diagnostic setup. These kinds of gadgets would make it possible to introduce cutting-edge diagnostic tests for controlling infectious disease epidemics onto the market. Additionally, they work well for point-of-care testing, especially in environments with limited resources. Figure 4 displays a schematic illustration of the device.

2. Conclusion and future scope

These papers investigate the important and quickly evolving topic of low-cost, material-engineered diagnostic devices. Developments in nanomaterial engineering have impacted current technologies and provided new, more practical approaches to testing. Compared to conventional medical devices, those built using these techniques are more resilient, sensitive, and easy to use. We first prioritised developing novel and distinctive assays that are easier to use and more sensitive than previous technologies, given that the development of sophisticated detecting mechanisms is essential to the development of such devices. Early disease identification and diagnosis are critical to effective disease therapy. There aren't many Arduino-based methods available right now for spotting bacterial infection. Our tests' suitability for use in a drinkable colorimetric apparatus. A portable Arduino-powered instrument was created to assess dangerous microorganisms in drinking water samples at the point of care and it was found that the disease could be detected with both selectivity and sensitivity.

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