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Integration of Microfluidic Devices and Smart Phones for Water Monitoring –A Review

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Abstract: Microfluidic innovation permits analytical system to be scaled down and incorporated into lab-on-a-chip devices, minimizing the volume of reagents consumed and of waste created, and permitting the utilization of low-fueled pumping system. Here, in this survey we will ponder the microfluidic sensors able to do quick, multiplexed detection. Electrochemical detection in a microfluidic stage offers numerous focal points, for example, compactness, insignificant utilization of instrumentation, and simple integration with electronics. In numerous parts of the world, be that as it may, the required gear for detection through electrochemical sensors is either not available or inadequately compact, and administrators may not be prepared to utilize these sensors and translate results, at last keeping its wide adoption. Presently a days, step by step the versatile innovation is growing quick. Joining these sort of versatile electrochemical procedures with such quickly developing advances will give advantage to the community. Toward a solution to water quality interventions, individuals have effectively demonstrate a microfluidic electrochemical sensor joined with a portable interface that identifies the different water contaminants and contaminations, appropriate for quick, reasonable, and point-of-care water monitoring. In this survey, we will first give the general foundation of microfluidic-based detection, versatile innovations available in combination with microfluidic sensors, and their integration.

Key Words: *Microfluidics, Mobile Sensing, Electrochemical Analysis, Water Quality.*

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I. INTRODUCTION:

Contaminated water is a genuine concern in numerous developing nations with serious wellbeing consequences especially for children and youngsters. MORE than one billion individuals have no access to a safe source of water, and as an immediate consequence, 1.6 million individuals pass on consistently from waterborne diarrheal diseases [1]. Water quality is basic for human wellbeing and habitation in various applications including the civil water distribution frameworks, refreshment and sustenance businesses, and space exploration missions. One of the significant difficulties is to have dependable, productive and financially savvy methods for water quality monitoring that can recognize contaminants in water distribution and/or capacity frameworks in a continuous way[2]. In Environmental analysis, there is great interest in in-situ monitoring which is permitting quick information acquisition. The challenge is to create compact devices that could be utilized in remote locations, which would eventually empower dynamic monitoring. Typically analysis methods are exorbitant and tedious, along these lines tending to the requirement for a simple and cost effective sensor is vital. A route to the generation of analytical instruments that can be operated in remote locations, enabling in-situ analysis is provided by micro total analysis system. The availability of a minimal effort, autonomous and deployable framework for the detection of contaminants in natural waters would along these lines be of critical advantage to nearby powers, environmental organizations and environmental analysts by encouraging high-recurrence monitoring of various locations at a cost which is more moderate than current technologies. Specifically, such a framework would accomplish consistence with the monitoring necessities recommended by the European Union's Water Framework Directive[4].

Microfluidics have turned into an important device over the previous decade to control, examine, and cooperate with small measures of fluid. Harsh chemicals and high temperature and pressure bonding processes required for the clean room processing is typically utilized for the Microfluidic device fabrication. However, recent advances in microfluidics have demonstrated quick, ease techniques for manufacturing these frameworks using low temperature bonding of laser cut channels, or wax impregnated paper to guide liquid through narrow action[5].

1.1 Basic Principle of microfluidics:-

When a fluid gets inside a pipe or in a channel the flow can show different behaviors in dependence of physical properties, flow rate and geometry of the system; basically it is possible to define two typologies of flux: laminar and turbulent. Laminar flux is characterized by parallel flow lines without any interference between each other; oppositely, if the flow lines are not parallel and they have some intersection or if there is a formation of vortex, the flow is called turbulent. In a turbulent regime there is mass transfer in the direction perpendicular to the wall of the channel, and this allows phenomena as mixing or heat transfer to be enhanced. A parameter that can give information about the characteristic of the flow in a pipe or channel is the Reynolds number, Re, and is defined as:
eq.1

$$Re = \frac{Lv\rho}{\mu}$$

where μ is the viscosity(kg/m*s), ρ is the fluid density(kg/m^3), and v(m/s) is the average velocity of the flow, L is a length scale and is equal to 4A/P where A is the cross sectional area of the channel and P is the wetted perimeter of the channel[6].

The manipulation of nanolitre to picolitre volumes of fluids on silicon chip surfaces has enhanced the synthetic sensors' micro reactors, which has in this way enhanced their detection limits. An articulate survey of stream material science in small micro scale and nano-scale fluidic devices is presented in the review article by Squires *et al*. [11].

II. DEVELOPMENT IN PAPER BASED MICROFLUIDIC SENSOR:

Because of the improvement of paper-based microfluidics in the previous couple of years, paper has turned into a promising stage for lab-on-a-chip devices in which extensive scale and complicated laboratory tests could be performed. Moreover, they allow for portable, on-site real-time detection which is crucial in many applications such as in the clinical, food and environmental sectors where simple and practical analytical devices are highly needed[7].

There are a variety of paper materials available to the user, although the choice is based mainly on the fabrication steps required in developing a device and also on the specific application area In the advancement of sensors and microfluidic technology, because of its wicking capacity, filter paper has seen widespread use in recent years to produce paper-based sensors[12,13,14,15]. Some key parameters which separates filer papers are being porosity, particle retention and flow rate. These papers does not hold the physical attributes thus new advancement occurred. Case in point, hydrophobic nitrocellulose membranes display a high level of non-specific binding towards bimolecular and are appropriate for immobilization of enzymes, proteins and DNA[16,13,17].

These sort paper based sensors brought about more steady and reproducible fluid flow. More propel way the Glossy paper have been rated as more appropriate stage for sensing technology[13]. Paper based sensor fabrication material and procedures to be picked when that meet the criteria of minimal cost, simplicity and effective production process. Procedures reported in the writing incorporate photolithography[18,19,20]. Analogue plotting [21], inkjet printing [22] and etching [16,23,15], plasma treatment [24,25], paper cutting [13,26], wax printing [27,28,29], flexography printing [30], screen printing [31], and laser treatment [12,32].

Techniques were picked relying upon the sort of material utilized and the kind of modification required. The microfluidic fabrication and designing procedures talked about here can be utilized to develop paper as one-dimensional (1-D) and two-dimensional (2-D) lateral flow system to more complex three-dimensional (3-D) microfluidic devices. The 3-D devices permit quick distribution of sample in the z-direction and for multiple assay procedures to be performed, yet as yet permitting sample volumes to be kept to minimum[19].

III. ANALYSIS:

Many techniques are available for Quantitative and Quantitative analysis of the water contaminants, food quality and other sensor application. Keeping in mind the end goal to build up a compact innovation which ought to look after simplicity, affordability and less power consumption quantitative examination is more reasonable. Quantitative investigation will yield quick results thus less tedious. Among the available methods, five most commonly used analytical techniques for quantitative analysis are colorimetric [19,20,33], electrochemical [31,34,16,23],chemiluminescence [35,36], electrochemiluminescence [37,38] and electrical conductivity [39,]. As we discussed, optical and the electrochemical techniques are more suitable as these are less power consuming methods and well suited transducers.

3.1 Colorimetric:

Consider the Colorimetric technique for quantitative analysis, really it is a semi-quantitative strategy yet result is adequate for analysis. It is most least difficult and a broadly utilized technique or paper based analysis. The adjustment in shading might be pictured by eyes which is because of the compound reaction in any sort of test. As of late, Ratnarathorn et al. [33] demonstrated the colorimetric detection of copper utilizing silver nano-particles (AgNP) on paper devices.

3.2. Electrochemical Detection

Electrochemical procedures often require a three-cathode system, that is, a counter electrode, reference electrode and working electrode. In making a paper-based electrochemical sensor, a three-electrode system is imitated on paper. This implies such a sensor could supplant the traditional electro analytical strategy where costly solid state electrodes are required. As examined before in Section 2.2, with a specific end goal to grow such an electrochemical sensor, an additional progression in the fabrication procedure is the deposition of electrode, more often than not as conductive inks, on the paper. Additionally, with a specific end goal to perform voltammetric tests a potentiostat is important which is low in force and can be made portable[13]. The common materials used for creating the electrodes are carbon inks for fabricating working and counter electrodes while silver/silver chloride ink is used for the reference electrode[31]. The electrode configuration is appeared in Figure. The sample solution was deposited on the focal point of the paper and it flowed to the reaction sites that contained the three-electrode system. The paper devices consisted of microfluidic channels, electrodes and electrical interconnections manufactured onto the paper substrate utilizing wax printing and screen printing. The three electrodes which were a working electrode, a counter electrode and reference electrode were made of graphite ink while the electronic wires were designed utilizing silver ink[13].

IV. RECENT DEVELOPMENT IN MOBILE SENSING:

Current advanced cell phones with numerous striking elements give a promising computerized stage to point-of-care (POC) diagnostics, mobile healthcare and bio-analytical requirements. Such devices are completely automated and outfitted with a high resolution camera, a capable processor with high storage limit, remote connectivity, real time geotagging, secure information administration, and cloud computing. Some major suppliers continue offering more elements and diminishing expenses for such devices in this to a great degree aggressive and lucrative business sector with 7 billion mobile phone clients. To be sure, advanced mobile phones have been upheld and popularized for health and fitness, diabetes and weight management, and blood pressure/pulse rate. More progressed bio-analytical applications incorporate PDA based microscopy, fluorescent imaging, imaging cytometry, electrocardiography, lateral flow assays, surface Plasmon resonance-based sensing, electrochemical sensing, immunoassays (IAs), and different applications. Along these lines, PDAs will significantly affect healthcare monitoring and administration as it will prompt transformation scene changes in diagnostics by empowering constant on location analysis and telemedicine opportunities in remote settings.

V. INTEGRATION OF MICOFLUIDIC DEVICES AND MOBILE SENSING:

As talked about before, better assets are available in the business sector we simply need to utilize them effectively. Here we will examine how to integrate every one of these assets to get the best sort of portable and reasonable point of care system. The assets consist of the diverse sort of available mobile applications to interface the electrochemical analyzer with the mobile and to gather the information.

Below figure demonstrate the proposed framework diagram in which all the three things are indicated like, Microfluidics based electrodes, Electrochemical analyzer and the advanced mobile phone interface.

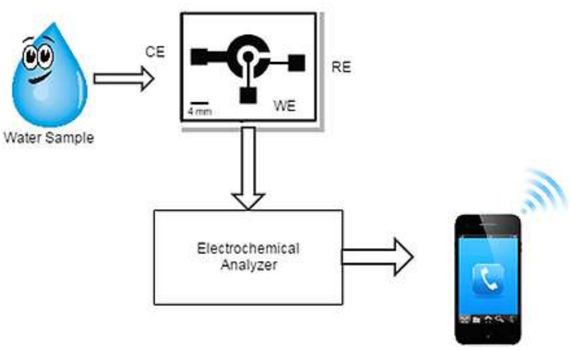

Figure 1 System Overview

The mobile application is the interface to the gadget. Its fundamental objective is to demonstrate the final result (safe or not safe to drink) instantly to the user by automatically interpreting the results from the data obtained and making a decision based on water safety guidelines. We decided to implement the interface for an Android phone because of its recent spread through under-served communities around the world. It communicates with the gadget through a USB cable through which, after every analysis, the information are transferred to the phone as a table of voltage estimations. The application processes the information and demonstrates the results to the client promptly. The result can be exhibited in two forms: as a curve in a graph or as a safe/not-safe guideline. The application likewise keeps a log of past results, which can be shown. Many symbolic, colored patterns can be used here by app to show the end result to the end user. The result can be quantitative or qualitative depending up on the nature of the test carried out. It may show for example Encircled Red Color for unsafe drinking water and Encircled Green Color for safe drinking water. It may also contain the quantity of the contaminants involved and in more advance manner number of contaminants present and in what quantity for quantitative analysis. Lopez-Ruiz and colleagues developed a paper-based colorimetric sensor for simultaneous determination of nitrite and pH in water samples [42].

CONCLUSION

Paper based sensing integrated with the advanced mobile phones giving diverse alternative to the detection and the analysis in various field like water monitoring, food safety, biomedical disease diagnosis health data management and health monitoring by routine checkups through mobile based sensing. This range is growing quick and giving more openings to the specialists. This field will stay in continuous improvement as it is additionally encouraging territory in light of the fact that the combination of latest advances and availability of that innovation with individuals. This combination of the innovation will have sway on life of nationals in this present day society.

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