Nanotechnology and Nanosensors, Part 1

(Technion - Israel Institute of Technology)

Peer-graded Assignment: Mini Project

Nanosensors in the Service of the Internet of Things (IoT)

Application of a Modified Screen-printed Electrode for the Real-time Sensing of Glyphosate in Paddy Field

Introduction

Glyphosate is a "broad-spectrum herbicide" which is currently the most widely used herbicide of the world. It is used in over 750 products for agriculture, forestry and urban applications (Guyton et al., 2015). Glyphosate has been detected in the air during spraying, in water, and in food. Although acceptable daily intake (ADI) level for glyphosate has been determined through toxicity tests (0.3 mg/kg bw/d, Europe), several reasons have been raised by experts to doubt the validity of these ADI values. This glyphosate which was once thought to be as safe as table salt (Preston, 2014) was classified in 2015 as "probably carcinogenic to humans" (Group 2A) based on animal studies (Guyton et al., 2015) by the International Agency for Research on Cancer (IARC). It has been proven to induce many other diseases as well (Guyton et al., 2015). In a country like Sri Lanka, rice farmers are heavily dependent on the use of glyphosate as a weedicide. In the year 2014, it was revealed in a study (Jayasumana et al., 2014) that glyphosate is linked to the chronic kidney disease epidemic prevalent in the rice farming districts of Sri Lanka over the past two decades. This study has further clarified that the toxic effect of glyphosate is caused when the weedicide gets in contact with ground water containing heavy metals that come from the soil or fertilizer. When this hard water gets into human consumption, it causes the kidney problem. Owing to these findings, the government of Sri Lanka banned the sale of glyphosate weedicide ("Sri Lanka First", n.d.).

Rationale: On this background, a nanosensor which could selectively detect glyphosate in field water would be helpful to know its presence and thereby take necessary actions. The signal detected by the sensor is transferred to the smartphone interface through wireless technology and the measurements are interpreted. The information thus generated is stored in the cloud storage that can be accessed by the agricultural officers. Establishment of such a database through this sensor would enable concerned authorities to monitor the glyphosate levels in field water and take necessary actions for control. Since it is not necessary to manually collect water samples for testing, a large area can be effectively monitored by a single officer simply by installing sensing devices at selected locations.

Objective: To develop a selective and sensitive nanomaterial modified sensor for the detection and effective monitoring of glyphosate levels in paddy field water.

Literature Review

Nanotechnology has provided high graded solutions to various problems in numerous fields such as medicine, biotechnology, manufacturing, agriculture, military etc. This has led to the evolution of nano-machines designed to perform pre-determined tasks. The concept of 'The Internet of Things' (IoT) which was proposed in the year 1999 has gained vast popularity in the present world of wireless communications. This concept has marked a high impact on various aspects of day to day life bringing up new terms such as e-commerce, e-health, e-agriculture, e-industry, etc. (Nayyar et al., 2017). The interconnection of nanosensors and nanodevices with the Internet has led to the development of a concept based on IoT called 'Internet of Nano Things' (IoNT). This new concept was introduced by Ian Akyildiz and Josep Jornet (Akyildiz & Jornet, 2010). This concept specifically deals with integrating nanoscale devices with communication networks to obtain data (Nayyar et al., 2017). This has opened a new area of research on nanosensors.

Molecularly imprinted polymers (MIP) allows highly selective detection due to specific binding between a target molecule and the polymer. Such MIPs have been used to develop various sensing platforms (Gui et al., 2018). Boric and boronic acid compounds undergo complexation reaction with diol moiety containing compounds through a reversible ester formation (Springsteen & Wang, 2002). This affinity reaction of boronic acids has been widely deployed as selective receptors to develop a sensor for compounds having diol functionality (Anzai, 2016). Since our compound of interest (glyphosate) is also having diol groups there is a possibility to utilize boronic acid derivative in a suitable sensing platform. Polymerizable boronic acid derivatives have also been made as monomers to form MIP. Out of the many boronic acid derivatives used in sensing applications, phenylboronic acid (PBA) has been the most extensively used type. Electrochemical transduction devices such as screen printed electrodes (SPE) can be modified with these MIPs using different techniques (Gui et al., 2018) to develop sensors with superior selectivity for a target molecule. The great versatility of SPEs in the ability to easily modify their working electrode with different nanomaterials makes them desired candidates to develop novel sensing platforms for different applications.

Methodology

A commercial screen printed carbon electrode (SPCE) will be used in this sensor as the main sensing platform and its working electrode surface will be modified through electropolymerization of the monomer solution containing the selected boronic acid derivative and the template (glyphosate). The template molecule can be removed afterwards using a suitable solvent such as an acid thereby leaving the sensor surface with specific binding sites that can accommodate glyphosate molecules. The sensitivity of the sensor may be enhanced (to achieve low detection levels) by using carbon nanotubes and/or gold nanoparticles owing to their excellent conducting properties.

This modified SPCE can be incorporated into a wireless electrochemical detector (WED) that interfaces with a smartphone/tablet. The design and characterization of such a simple, small wireless electrochemical detector were reported in a recent paper (Ainla et al., 2018). The signal detected by the WED upon binding of the target molecule on the imprinted cavities of the SPCE will be sent to the smart phone through wireless technology. A specially developed mobile application will read this signal and will interpret the amount/concentration of glyphosate in field water. The information thus collected will be sent to cloud storage via the mobile network. This information gathered from all farmers will be saved on the database with the specific location of data collection.

Conclusion

Nanosensors have played a vital role in many fields providing revolutionary solutions to many problems. The incorporation of IoT with nanosensors is an open door to advance further research on nanosensors with a new focus. Development of this sensor will enable effective monitoring of glyphosate levels in field water. Since the sensing device can be developed at a relatively low cost, such a technology would be easily adaptable for a developing country like Sri Lanka. Furthermore, it will help the authorities in their effort to discover a sustainable solution to the chronic kidney problem associated with excessive use of weedicides. Further research is necessary to be conducted after a pilot study so as to assess the performance of the sensing device under field conditions, and necessary adjustments can be done accordingly.

References

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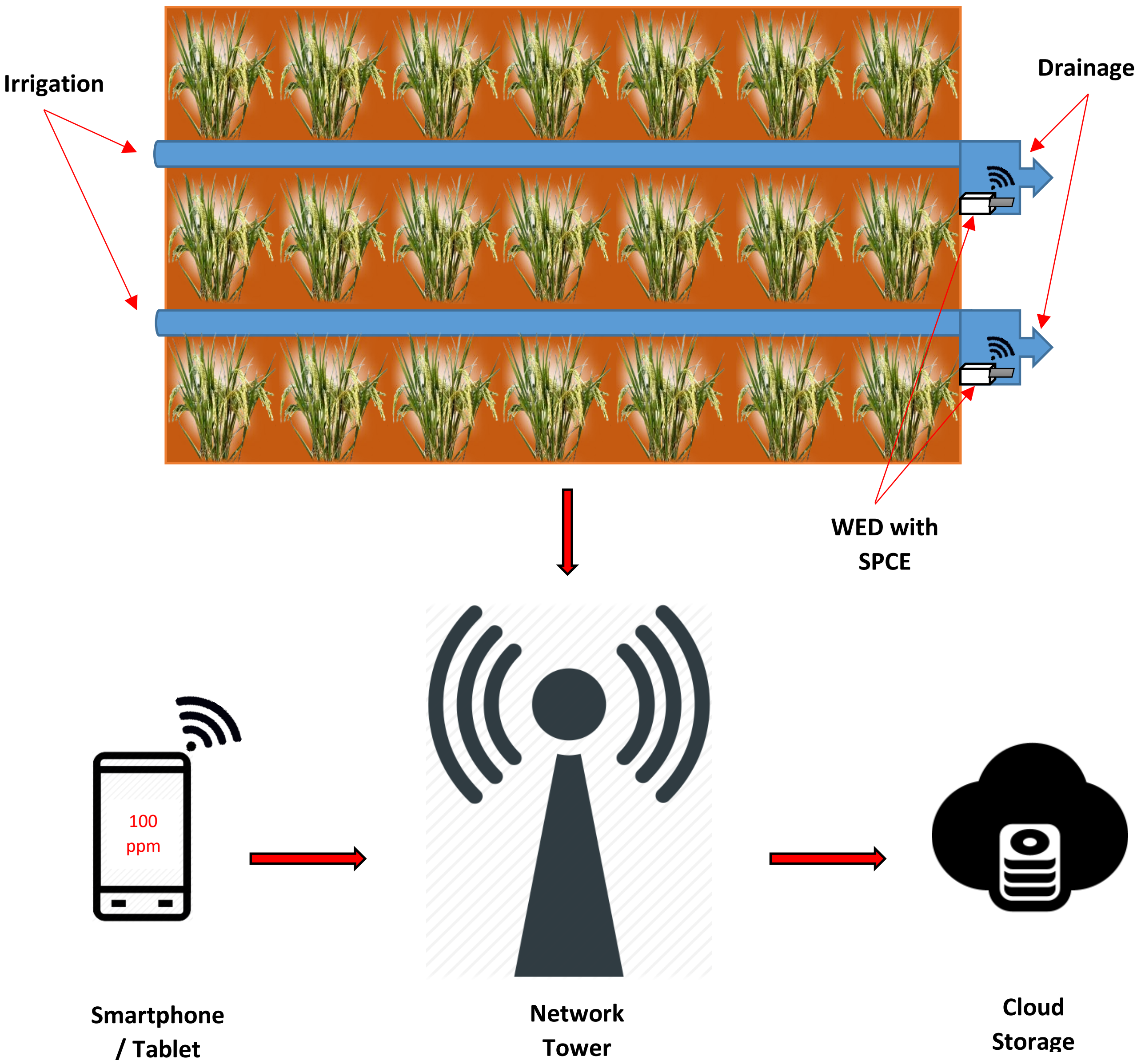

Schematic Representation of the Sensor Setup in a Paddy Field