Internet of Things (IOT) based Portable Electrochemical Sensing Platform for Salmonella Point-of-Care Diagnosis

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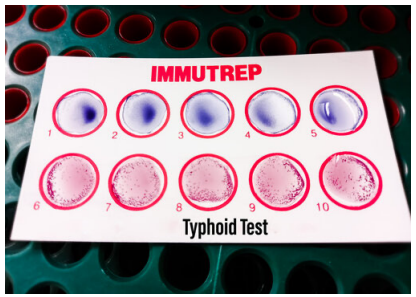
BACKGROUND

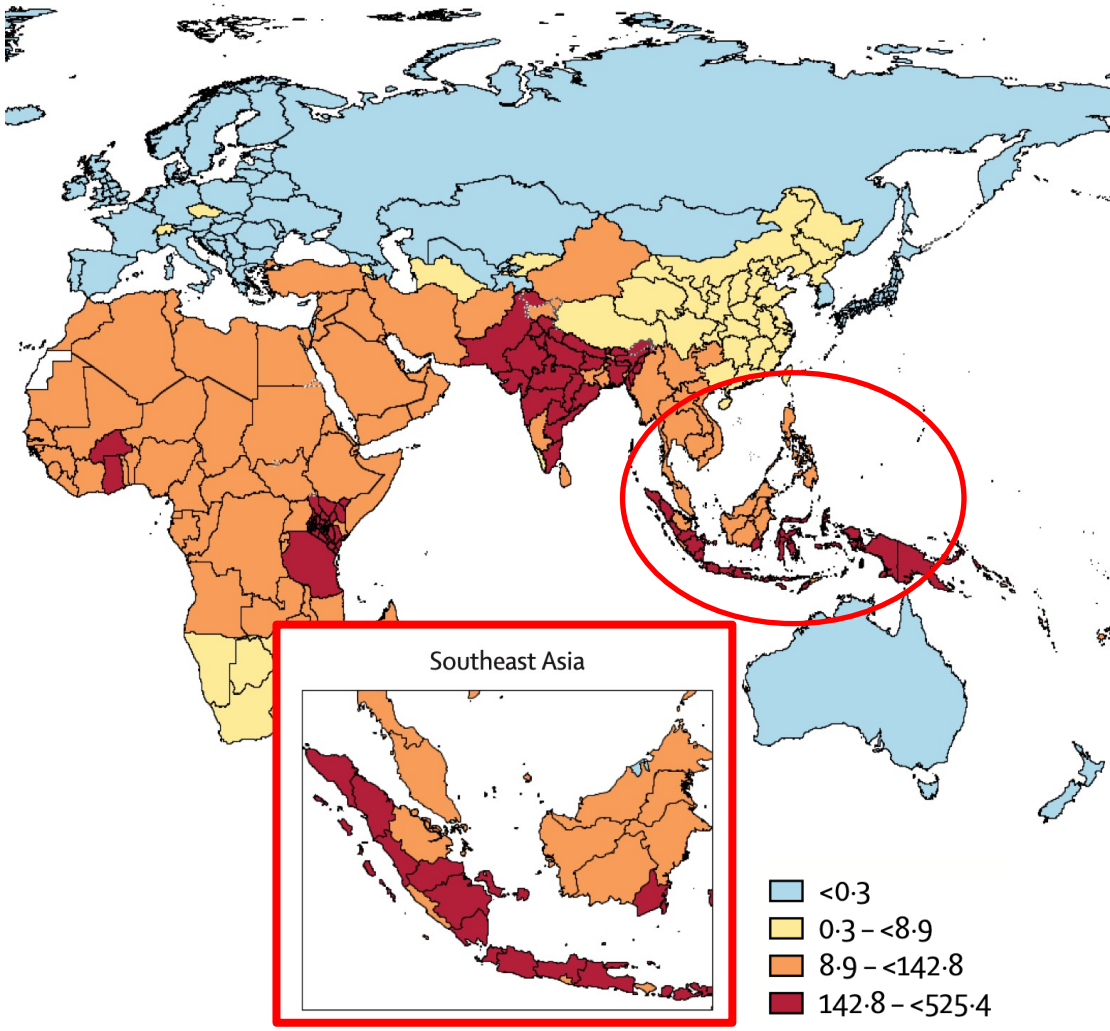
Typhoid fever

- Caused by the ingestion of *Salmonella enterica* serotype Typhi
- Lead to gastrointestinal complications and life-threatening typhoid fever.
- Antibiotic resistance threat
- Chronic carrier



Detection method

- Antigen-antibody test (Widal test), (rapid, but has cross reactivity issue)
- Blood culture method (laborious & time consuming)
- Mostly qualitative



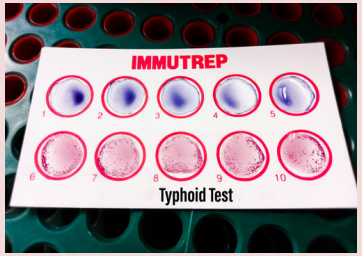
Age-standardised DALY rates (per 100 000) by location, both sexes combined, 2019

Source: Global Health Metrics, www.thelancet.com

TARGETS

Infected patient

Conventional detection methods (3-5 days)



- ✗ Misdiagnosis
- ✗ Late treatment can be fatal

Portable biosensor device (Detection time: ~24 hours)

Digitalization of data

Point-of-care diagnosis

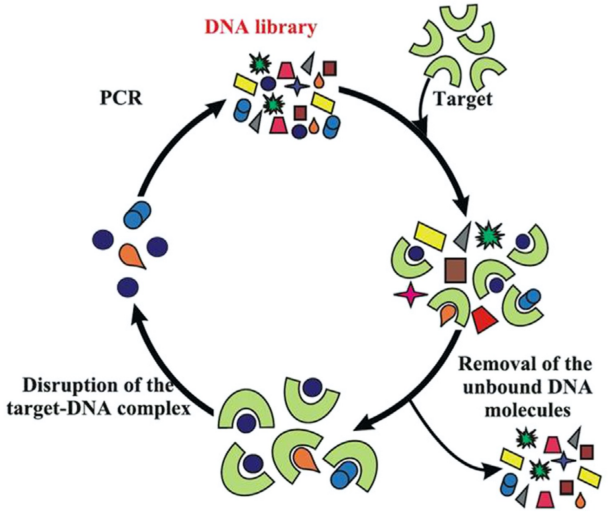
- ✓ Specific and fast detection
- ✓ Early treatment
- ✓ Early outbreak detection
- ✓ Carrier screening

Images downloaded from: itlbiomedical.com, flaticon.com

PROPOSED METHOD

1 Bioreceptor Development

- Aptamer
- Single strand DNA probe

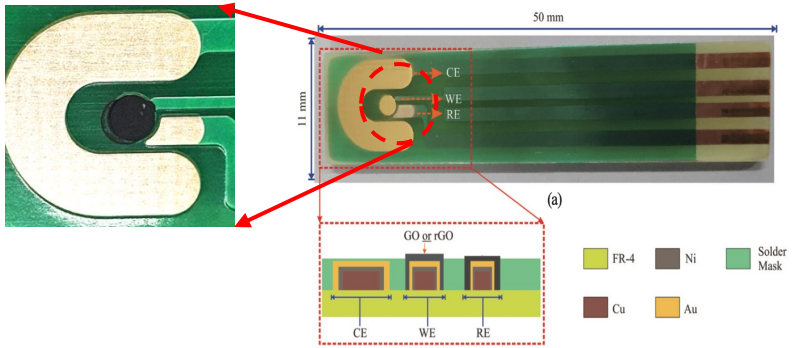


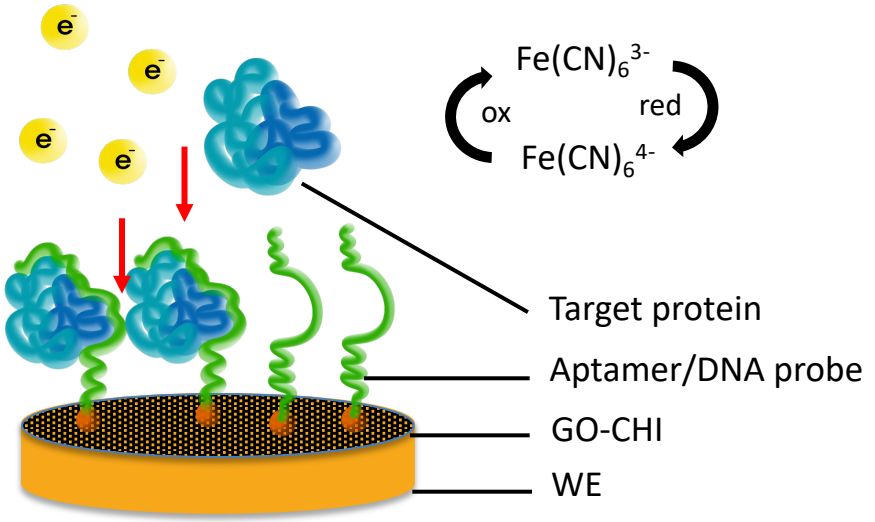
Aptamer development through SELEX process

Kumar, Alok, et al. "Aptamer technology for the detection of foodborne pathogens and toxins." *Advanced biosensors for health care applications*. Elsevier, 2019. 45-69.

2 Sensor Development

- Printed circuit board-based miniaturized electrode on FR-4 substrate as Lab on PCB
- All gold electrodes
  - Working (WE)
  - Counter (CE)
  - Reference (RE)
- Modification of WE with graphene oxide-chitosan (GO-CHI) nanocomposite to improve current signal
- Bioreceptor immobilization on WE

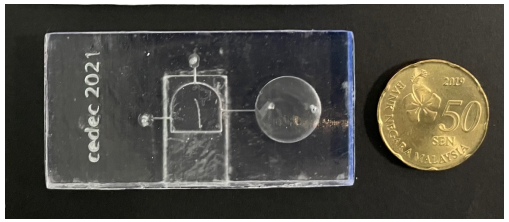




PROPOSED METHOD

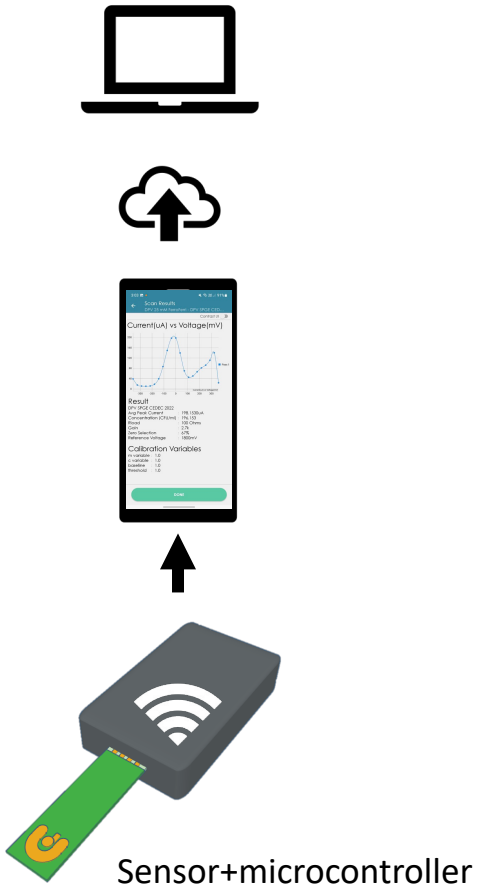
3 Microfluidic Channel

- Resin-based microfluidic channel using a resin 3D printer



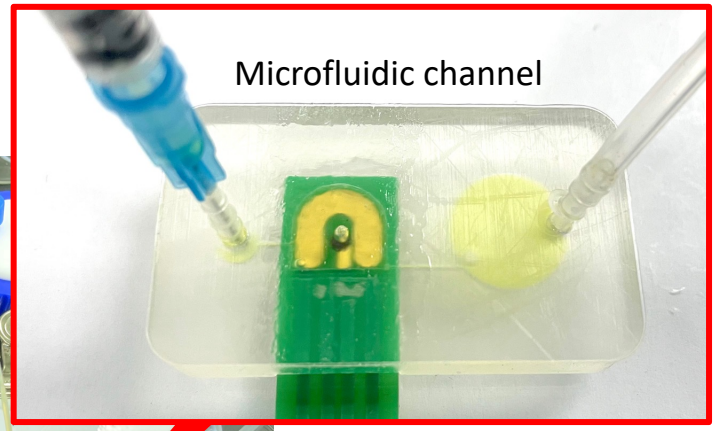
4 Integration of microcontroller & IoT

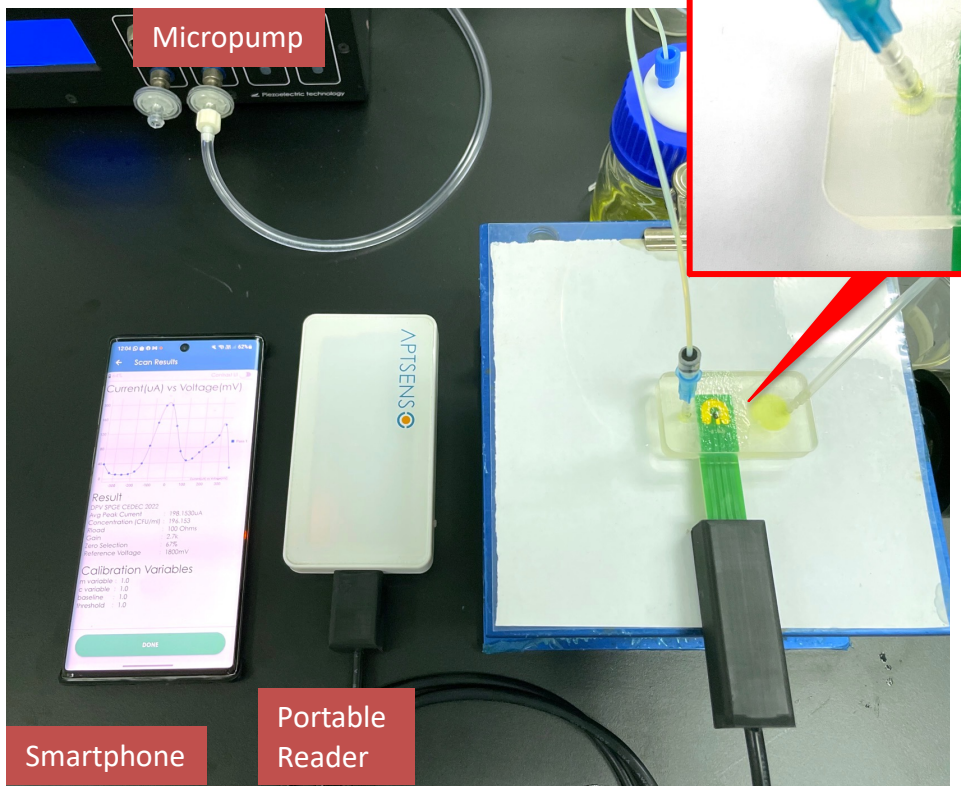
- Integration of developed sensor with a microcontroller, equipped with Wi-Fi connectivity
- Detection can be conducted using smartphone & uploaded to cloud database
- Cloud database can be access by researchers or heath care providers



PROPOSED METHOD

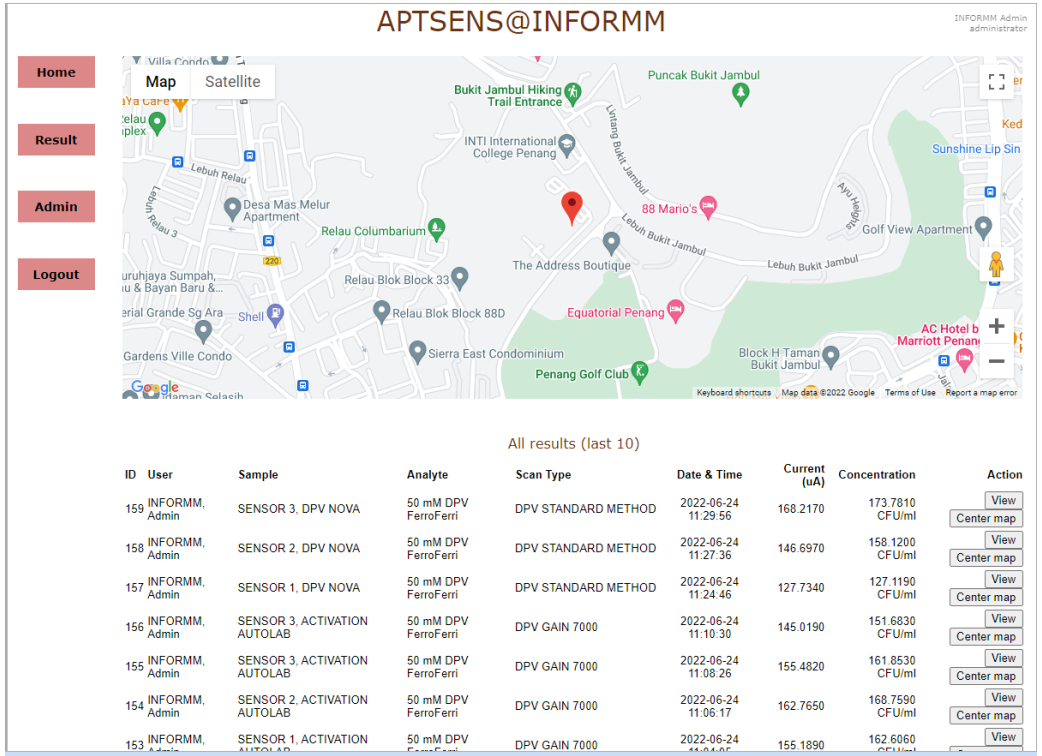
Portable reader





Electrochemical measurement in 25 mM ferri/ferrocyanide redox solution : Differential Pulse Voltammetry (DPV)

IoT system



ID	User	Sample	Analyte	Scan Type	Date & Time	Current (uA)	Concentration	Action
159	INFORMM, Admin	SENSOR 3, DPV NOVA	50 mM DPV FerroFerri	DPV STANDARD METHOD	2022-06-24 11:29:56	168.2170	173.7810 CFU/ml	View Center map
158	INFORMM, Admin	SENSOR 2, DPV NOVA	50 mM DPV FerroFerri	DPV STANDARD METHOD	2022-06-24 11:27:36	146.6970	158.1200 CFU/ml	View Center map
157	INFORMM, Admin	SENSOR 1, DPV NOVA	50 mM DPV FerroFerri	DPV STANDARD METHOD	2022-06-24 11:24:46	127.7340	127.1190 CFU/ml	View Center map
156	INFORMM, Admin	SENSOR 3, ACTIVATION AUTOLAB	50 mM DPV FerroFerri	DPV GAIN 7000	2022-06-24 11:10:30	145.0190	151.6830 CFU/ml	View Center map
155	INFORMM, Admin	SENSOR 3, ACTIVATION AUTOLAB	50 mM DPV FerroFerri	DPV GAIN 7000	2022-06-24 11:08:26	155.4820	161.8530 CFU/ml	View Center map
154	INFORMM, Admin	SENSOR 2, ACTIVATION AUTOLAB	50 mM DPV FerroFerri	DPV GAIN 7000	2022-06-24 11:06:17	162.7650	168.7590 CFU/ml	View Center map
153	INFORMM, Admin	SENSOR 1, ACTIVATION AUTOLAB	50 mM DPV FerroFerri	DPV GAIN 7000	2022-06-24 11:04:05	155.1890	162.6060 CFU/ml	View

IMPACT

Scientific & Technological

- Development of highly specific and sensitive aptamer towards Salmonella protein (Hemolysin & YncE)
- Miniaturized sensor platform using printed circuit board as Lab on Printed Circuit board (LoPCB)
- Addition of graphene oxide nanomaterials to improve current signal
- Portable electrochemical biosensor as Internet of Salmonella Things (IoST) for Salmonella POC diagnosis

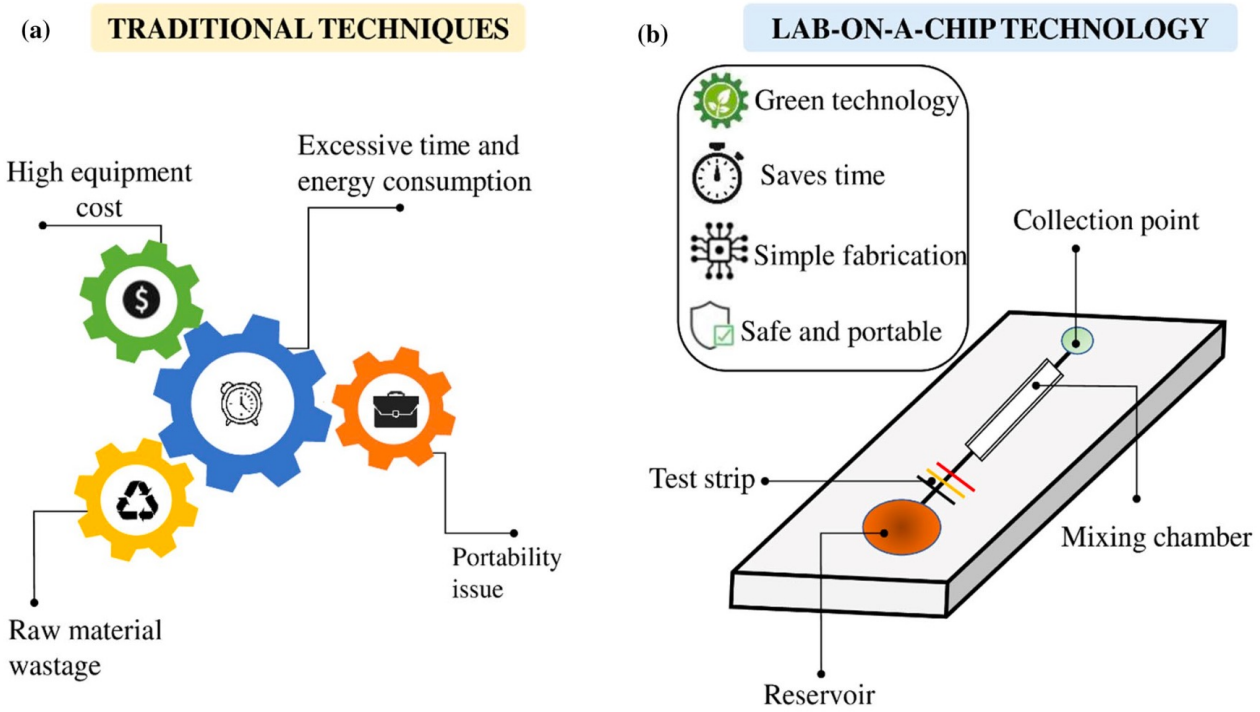
Societal

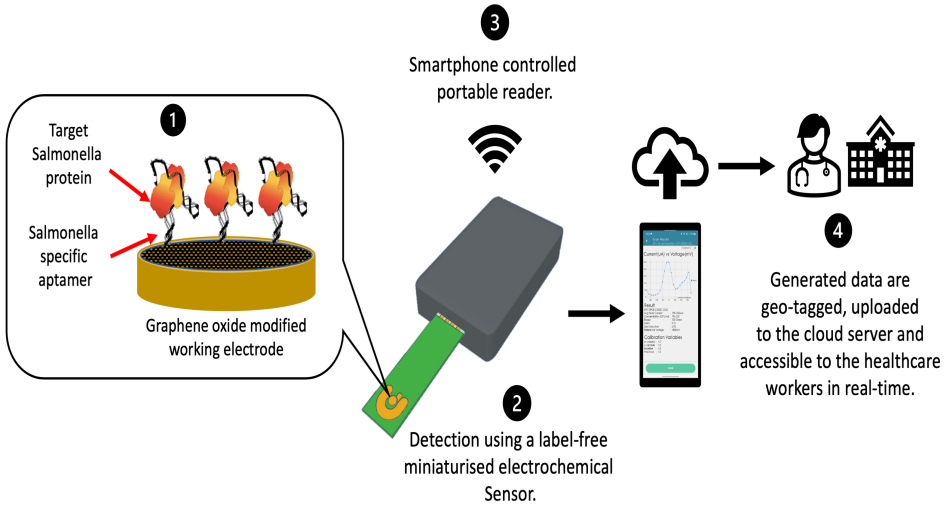
- Simplified the system for analyse the effects of environment and socioeconomics on Salmonella infection
- Awareness to community in implementing digitalized system in community for salmonella outbreak tracking
- Impact to digitalized data in study the salmonella pattern in community
- Reduce the gap between detection and action in expedite the monitoring system

Collaborative

- Internal and external collaboration (University, company and hospital)
- Engagement with government and enforcement agency
- Local community engagement in implementing the developed system
- Medical practitioner in improvised the developed system

IMPACT





Adithya Sridhar et al., Environmental Chemistry Letters, Lab-on-a-chip technologies for food safety, processing, and packaging applications: a review, 2021

- Smartphone based monitoring system in order real time tracking system to predict the pattern of outbreak
- Collaborative with local community, enforcement agency and medical institutions in awareness of implementing the Internet of Salmonella Things (IoST) towards to impact in environmental and socioeconomics

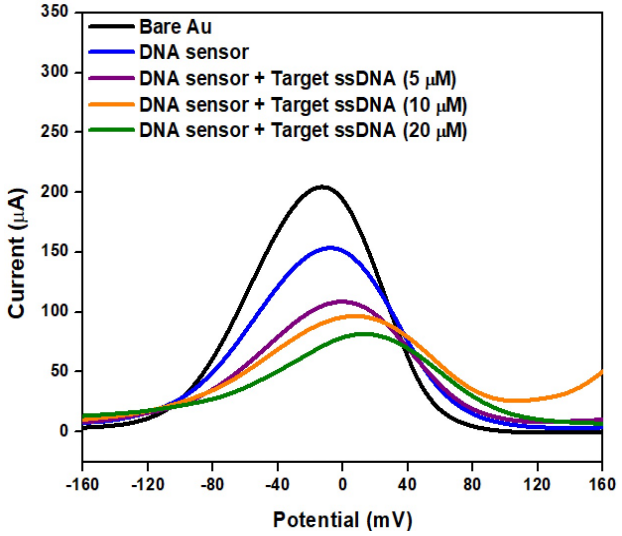
OUTCOME

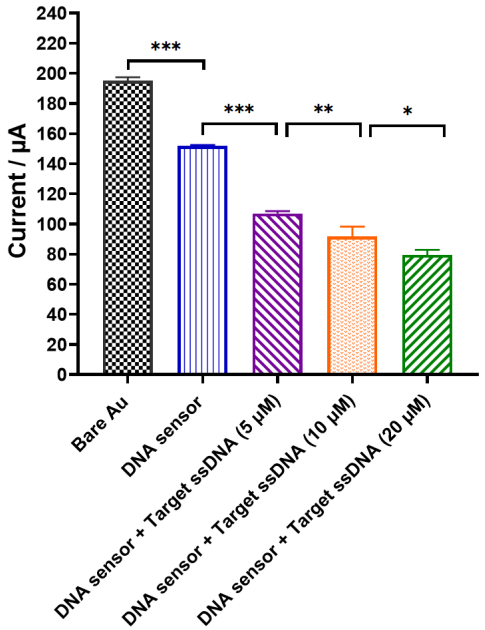
Salmonella ssDNA detection using DNA probe

Scientific effect:

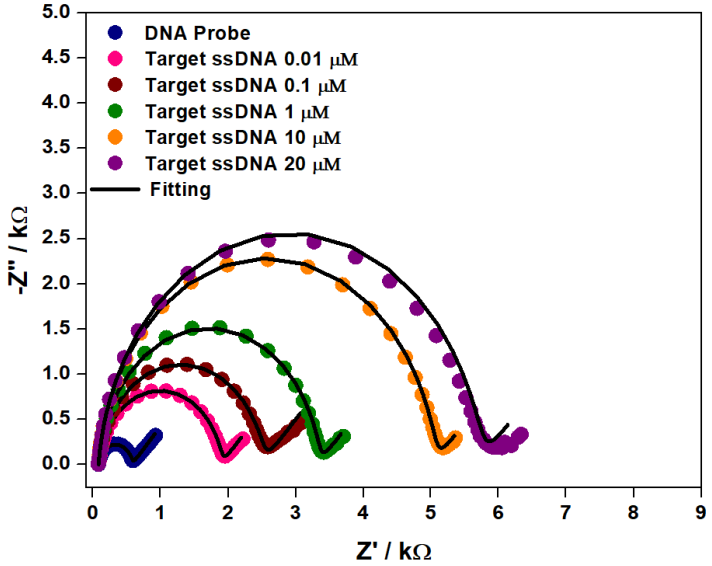
- ✓ Miniaturization of the sensing electrode by implementing lab on printed circuit board technology
- ✓ Improvised the limit of detection
- ✓ Be able to proof the detection using the DNA and protein based detection using LoPCB technology

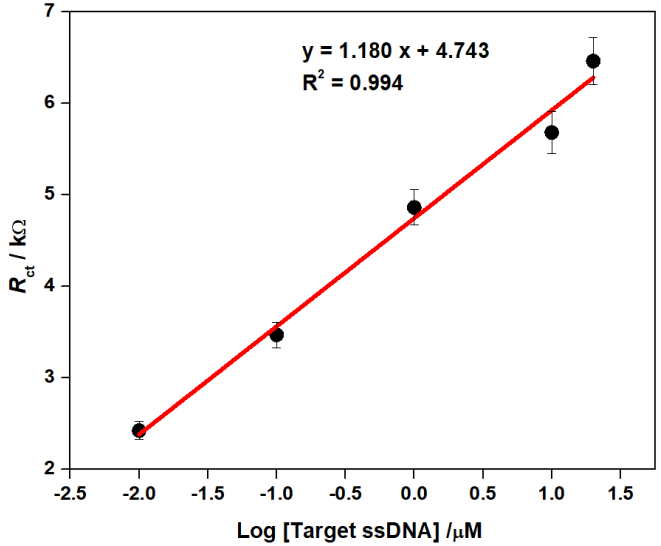
- Differential pulse voltammetry (DPV) for Salmonella DNA sensor





- Limit of detection (LOD) determination using electrochemical impedance spectroscopy (EIS)



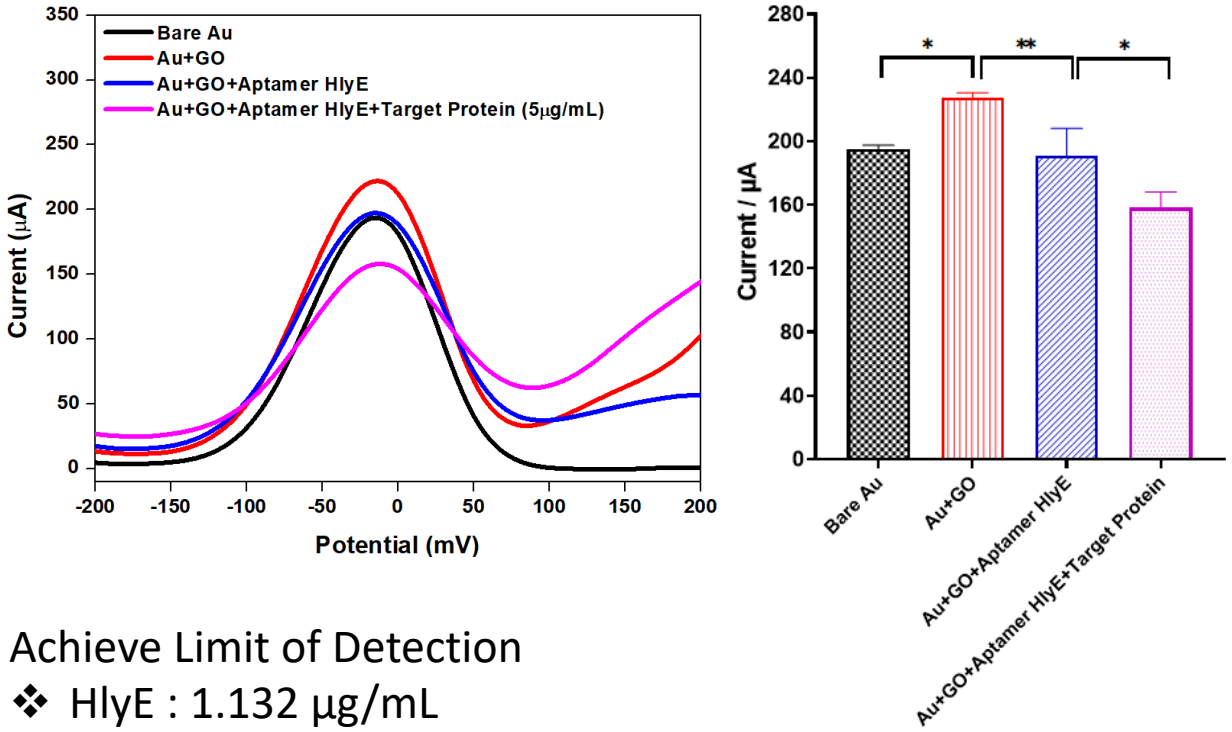


LOD = 3 s/m (s=0.0030; m=1.180)
= 0.0076μM / 7.6 nM

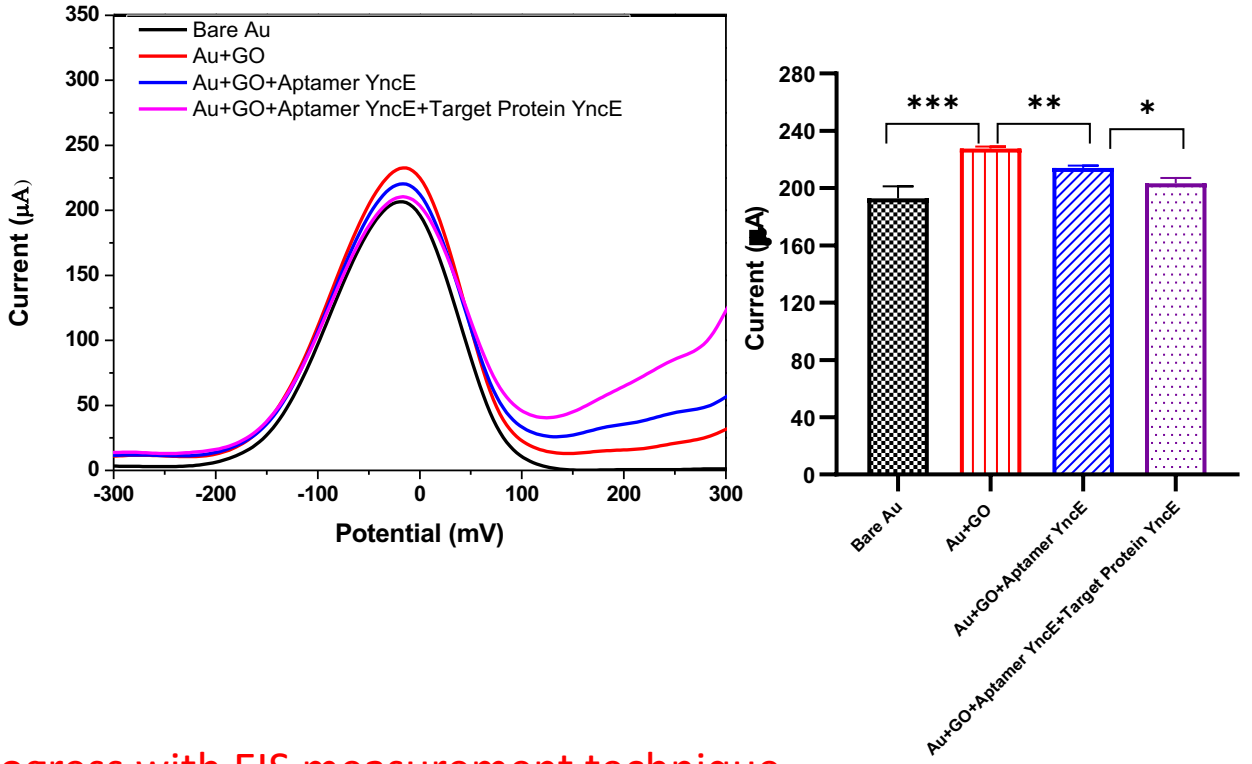
OUTCOME

Salmonella protein detection using aptamer

- Differential pulse voltammetry (DPV) for Salmonella hemolysin protein (HlyE) detection



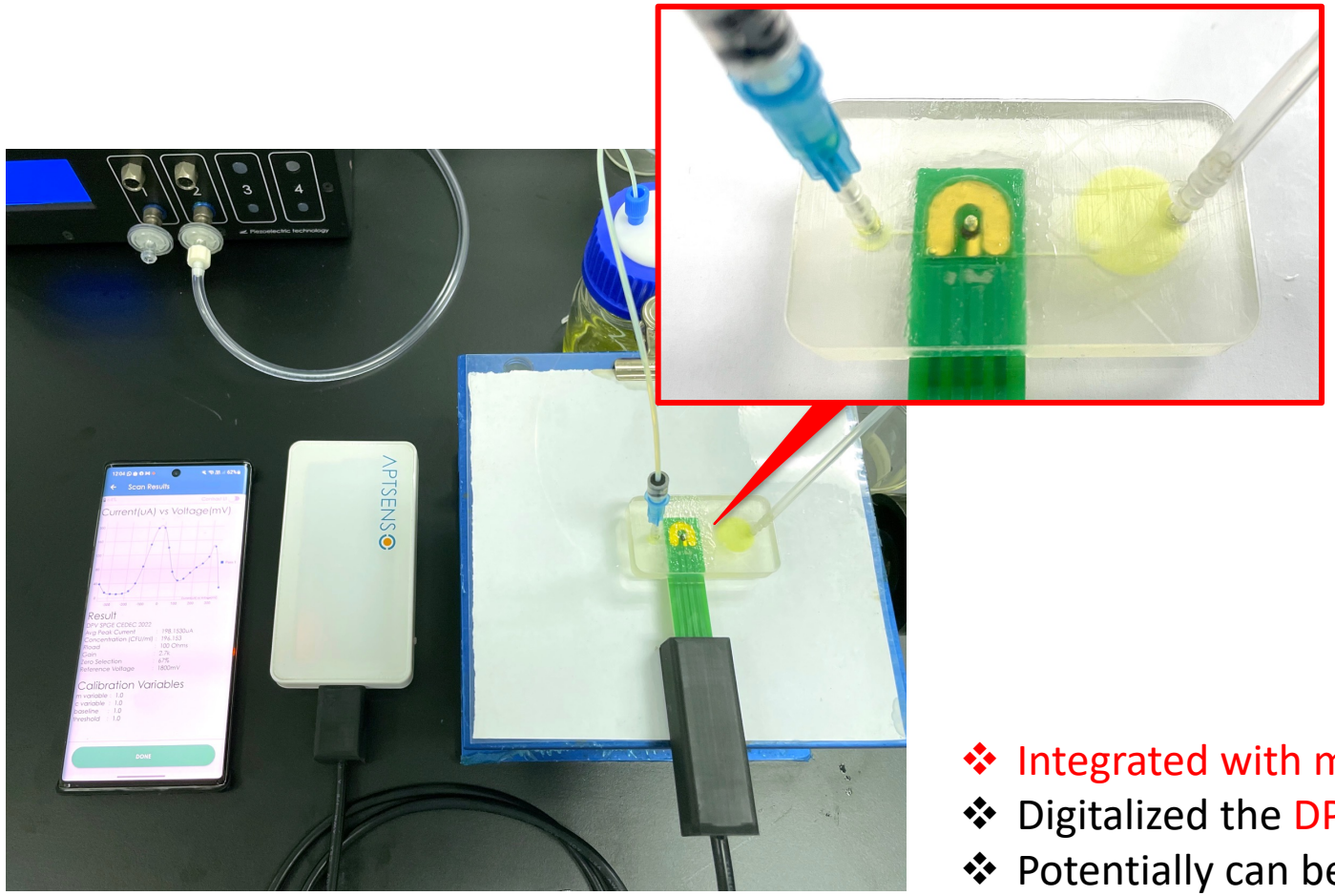
- Differential pulse voltammetry (DPV) for Salmonella YncE protein detection

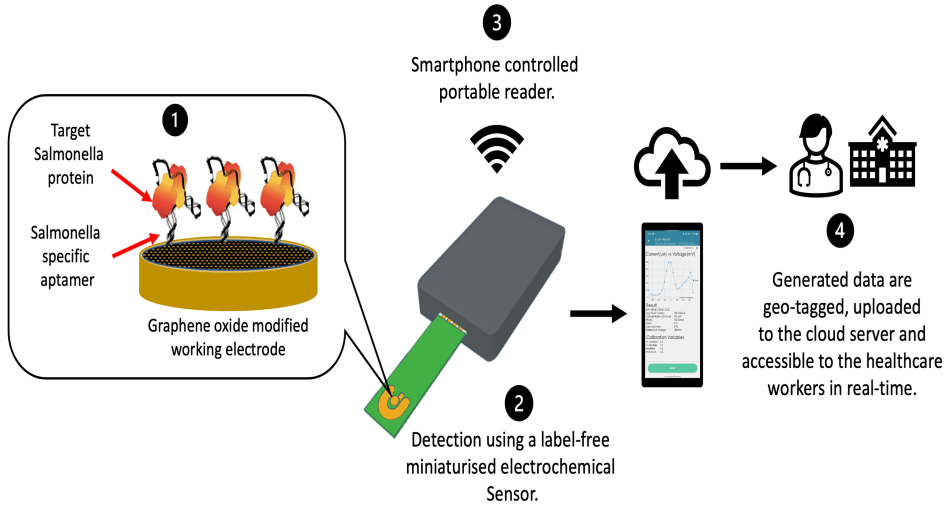


Achieve Limit of Detection

- ❖ HlyE : 1.132 µg/mL
- ❖ YnCE: 1.543 µg/mL * The accurate LoD still in verification progress with EIS measurement technique

OUTCOME





- Integrated with microfluidic system on minimized the volume of sample
- Digitalized the DPV signal with smartphone for onsite detection system
- Potentially can be improved with the machine learning processing at the cloud to predict the behavior of salmonella outbreak at local community with Internet of Salmonella Things (IoST)

CONCLUSION

- Improvised the miniaturization and limit of detection for electrochemical sensing platform for salmonella detection
- Proof the concept for developed system be able to detect the infection patient and carrier
- The integration of IoT system into biosensor can be a promising diagnostic tool for digital based POC Salmonella detection and monitoring system as Internet of Salmonella Things (IoST)
- The developed sensing platform can be use interchangeably with any other bioreceptor to improve diagnosis of infectious diseases
- **Future work**, integrate with cloud services and machine learning processing to create the prediction system for behaviour of salmonella outbreak in local community

THANK YOU

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