Development of IoT indirect BOD monitoring system based on electronic nose technology

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***Abstract*— Smell is a good indicator of water quality. In this work, we develop the IoT smelling device to estimate BOD value of wastewater based on electronic nose technology. The BOD monitoring device consist of four important modules as follow: (1) sensor module, (2) power module, (3) microprocessor (MPU) module and (4) GSM/GPRS module. The system was designed for ease of use and easy to installation in the remote field area. The indirect BOD measurement by using electronic nose was studied to develop mathematical model for the device's firmware. The result show that e-nose technology can be used to estimate the BOD value of wastewater with R-square value is 0.8817. It need more experimental detail, as to quantify the sensor signal and calibrate its value to BOD, thereby opening the opportunity for IoT indirect BOD measurement monitoring based on e-nose technology to compete conventional BOD evaluation techniques in the future.**

I. Introduction

Electronic nose or E-nose, is wildly used in many applications such as food and beverage, healthcare, agriculture, cosmetic etc. In general, E-nose system consists of three paths, including an array of gas sensors, air circulation system, data acquisition module and data analysis program, which can detect volatile molecules in the air or odorous liquid and solid samples [1-2]. For water monitoring application, there are many reports using E-nose to detect the volatile organic compounds in wastewater. Recently, studies on the monitoring of BOD from sewage treatment plants using e-nose with non-specific sensor array and neural networks were reported. Stuetz et al. demonstrates the possibility of measuring wastewater BOD using an e-nose in combination with artificial neural networks. They show that non-invasive method may serve in on-line bioprocess monitoring. However, the linear relationship was only apparent for short time periods, whereas the analysis over a longer term was non-linear [3].

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In this work, we study the new method for indirect BOD measurement by using E-nose technology. The data of electronic nose was analyzed with BOD value to develop mathematical model for using in the IoT device's firmware. Finally, the IoT indirect BOD monitoring system was designed to use in real world application.

II. Current Results

A. IoT indirect BOD monitoring system based on E-nose technology.

In this work, the IoT indirect BOD monitoring prototype was developed considered affordability, robustness and can operate in real world application. The Fig.1 present the concept of this development. The system was designed for ease of use and easy to installation. By using solar panel and battery, the station can operate in the remote area without electricity. The station connects to internet and cloud server by GSM/GPRS module which can be replace by other IoT protocal, for example LoRaWAN and NB-IoT, in the future.

The block diagram of IoT indirect BOD monitoring system was showed in Fig. 2. The device consists of four important modules as follow: (1) sensor module, including water sensor, E-nose and GPS, for measurement of water quality parameters and location of the station. (2) power module, including solar panel and battery, (3) microprocessor (MPU) module for collect and analyze the data and (4) GSM/GPRS module for connect to the internet and upload data to cloud server. To reduce the amount data and prevent rubbish information, the data from each station was collected and analyzed by MPU unit before transmit to cloud server. User can access to water information by using mobile device via website or mobile application.

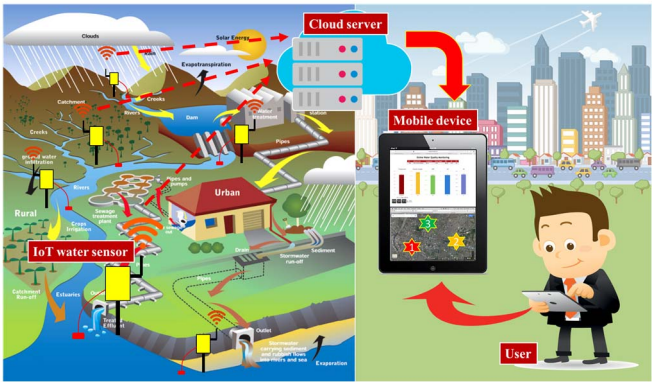

Figure 1. Concept of IoT water sensor based on Electronic Nose Technology

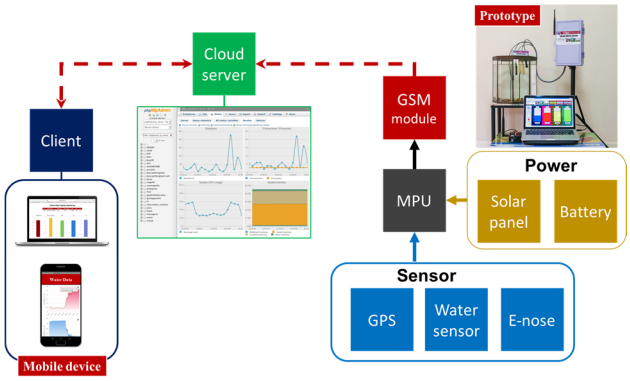

Figure 2. Block diagrem of IoT indirect BOD monitoring system based on E-nose technology

Before using the device in real application. The indirect method of BOD measurement based on E-nose technology was studied to develop mathematical model for predict the BOD level. This mathematical model will be embedded in the firmware of BOD station.

B. The result of indirect BOD measurement using E-nose

The in-house E-nose device were used to test with water samples from four different sources, including Samsen canal, Nanglernge canal, Praem Prachakom canal and Sansab canal. The sample was collected every week for 6 weeks and compare to tap water as reference. The samples were collected and analyzed for BODs using conventional laboratory technique, and odor profiles using an in-house E-nose. The samples for e-nose measurement could equilibrate at 20.0 ± 2.0 °C within 4 h after the collection.

The raw data from E-nose was analyzed using principal component analysis (PCA) method and plotted in 3 dimensions as show in Fig. 3, it was also found that the wastewater samples from each site have specific odor profile and e-nose can discriminate the different of smell. The sensing response were calculated and compared with BOD value from conventional laboratory technique as show in Table. 1. After that, BOD data and sensing response were plotted using Excel. The estimated Trend-line and R-squared value were calculated as show in Fig. 4.

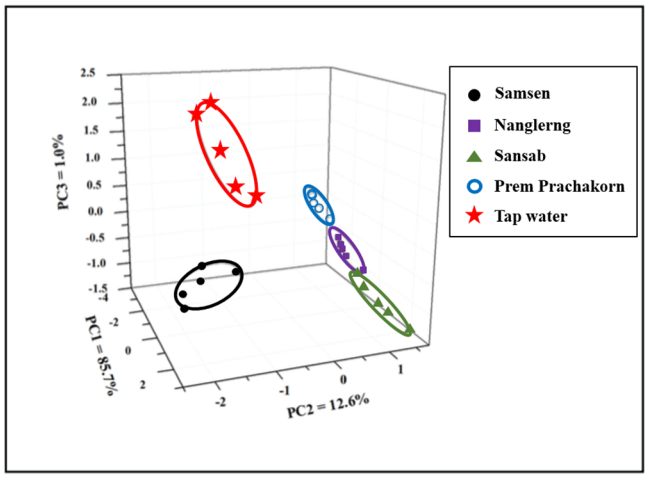

Figure 3. 3D PCA result of water sample from four different source compare with tap water.

TABLE I. DATA OF BOD VALUE AND E-NOSE SENSING RESPOINSE

Water sample source	BOD value (mg/L)	E-nose sensing response (%)
1. Tap water	1	0.99
2. Prem Prachakorn	7	6.70
3. Sansab	16	8.52
4. Nanglerng	21	11.80
5. Samsen	46	17.71

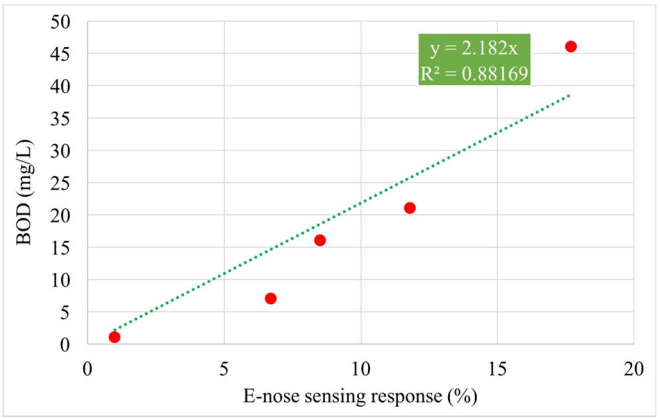

Figure 4. Correlation plot between BOD value and electronic nose sensing response

From the correlation graph as show in Fig. 4, it was found that the correlation between e-nose sensing response and BOD value tends to be linear which can be fitted with the equation as follow:

$$y = 2.182x \quad (1)$$

where y is BOD value (mg/L)

x is E-nose sensing response (%)

The R-square value of this equation is 0.8817 which is in the acceptable range. However, this can be improved by use more experimental data of BOD value and E-nose sensing response. From this work, it can be concluded that e-nose technology can be used to estimate the BOD value of wastewater. It need more experimental detail, as to quantify the sensor signal and calibrate its value to BOD.

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