



2019「中技社科技獎學金」

2019 CTCI Foundation Science and Technology Scholarship

境外生研究獎學金

Research Scholarship for International Graduate Students



Environmental safety based on novel machine learning techniques and electrochemical sensors

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Abstract

This research mainly focuses on development of advanced machine learning technologies and fabrication of electrochemical sensors for environmental safety. We have developed air quality warning systems based on PM_{2.5} and ozone soft sensors using novel approach of Bayesian regularized neural network via forward feature selection and damped least squares neural network with greedy backward elimination respectively. These low cost and accurate monitoring systems and soft sensors can easily replace the existing expensive big instruments for air quality. Furthermore, we have fabricated electrochemical sensors for detection of water pollutants hydroquinone and nitrophenol.

Research Focus

Graphical illustration of air quality warning system based on novel PM_{2.5} soft sensor

Architecture of BRNN estimation system

Architecture of DLSNN estimation system

Electrochemical mechanism of 4-NP

Electrochemical mechanism of HQ

Research Results

Table 1: Performance evaluation of air quality warning system

	Classified +1	Classified -1
True class +1	984	21
True class -1	11	571
Misclassifications= 32, Correct= 1555		
Accuracy= 98%, Recall= 0.98, F1-score= 0.983		

SEM of (A)3D flower ZnO, (B)fmwcnts, (C)ZnO/fmwcnts used for 4-NP detection

SEM of (A)ruskin michelle ZnO, (B)fmwcnts, (C)ZnO/fmwcnts used for 4-NP detection

DPV analysis and corresponding calibration curve of 4-NP detection

DPV analysis and corresponding calibration curve of HQ detection

Summary

- ✓ We have proposed novel methodologies including BRNN/FFS and DLSNN/GBE for development of PM_{2.5} and ozone soft sensors for estimating pollutant concentrations.
- ✓ SVM and KNN classifiers are used for the development of warning systems based on PM_{2.5} and ozone estimations respectively for attaining quick response.
- ✓ Descriptive statistics, seasonal variations, and correlation with various factors of particulate matter and ground-level ozone in Taiwan is evaluated as part of the research.
- ✓ All the performance metrics evaluated returned perfect results for the proposed air quality warning systems indicating its high efficiency.
- ✓ The fabricated 4-NP and HQ sensor exhibited excellent selectivity, good reproducibility, high stability, and repeatability which are the traits of a good electrochemical sensor.

Selected Journal Publications

- ✓ Balram Deepak, Kuang-Yow Lian, and Neethu Sebastian. "Air quality warning system based on a localized PM_{2.5} soft sensor using a novel approach of Bayesian regularized neural network via forward feature selection." *Ecotoxicology and environmental safety* 182 (2019): 109386.
- ✓ Balram Deepak, Kuang-Yow Lian, and Neethu Sebastian. "Ultrasound-assisted synthesis of 3D flower-like zinc oxide decorated fMWCNTs for sensitive detection of toxic environmental pollutant 4-nitrophenol." *Ultrasonics sonochemistry* 60 (2020): 104798.
- ✓ Balram, Deepak, Kuang-Yow Lian, and Neethu Sebastian. "Synthesis of a functionalized multi-walled carbon nanotube decorated ruskin michelle-like ZnO nanocomposite and its application in the development of a highly sensitive hydroquinone sensor." *Inorganic Chemistry Frontiers* 5, no. 8 (2018): 1950-1961.

Sincere thanks to Ministry of Science and Technology, Taiwan, R.O.C., for financial support under MOST 107-2221-E-027-114.



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