PLANAR ELECTROMAGNETIC SENSORS ARRAY FOR NITRATE AND SULPHATE DETECTION

ALIF SYARAFI BIN MOHAMAD NOR

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Masters of Engineering (Electrical)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

FEBRUARY 2015

Specially dedicated to *Umi* and *Abah*
Greatest physical and mental supporters

ACKNOWLEDGEMENT

Praise to Allah S.W.T., the Most Gracious and the Most Merciful, who gave me strength and guidance to complete this thesis. There is no power and knowledge that could challenge Him. Without His permission, I will be powerless and unable to gain knowledge and experience which are needed to complete this thesis.

My deepest gratitude to my supervisor, Dr Mohd. Amri bin Md. Yunus for his support, advice, and supervision. Without his consistant guidance and constructive critisms together with intelligent opinions throughout this research, the research would fail and unachievable. Besides, I also would like to thank my co-supervisor, Dr Sophan Wahyudi bin Nawawi for his supportive critisms and useful guidance during this research. Without his guideline as an experienced researcher, this research would be incompleted.

Apart from that, I would like to thank my mother and father who play a pivotal role in my life. They always pray for my success, offer pieces of advice and serves a useful guide for my taken path. Not forgotten, my little brother and sister which always support me from behind. I also would like to express my thanks to all my research members and staffs from the Sensors and Actuator Laboratory which always support and guide me in completing this research.

Finally, special thanks to the Minister of Higher Education of Malaysia and Universiti Teknologi Malaysia for providing the financial support for my research. Besides, these organizations also allowed me to learn and explore more from my research due to their supportive team member, provided laboratory equipment and serving the good research environment for the researchers.

ABSTRACT

This work expounds the development of three types of sensor arrays based on planar electromagnetic for environmental monitoring. Three types of sensor array are proposed: parallel, star, and delta. The modeling and simulation of all types of sensor array have been carried out to calculate the sensor's impedance value. The contamination state has been simulated by altering the electrical property values of the environment at the model subdomain to represent water contamination. The simulation results agree with the experimental trends. The star array configuration shows the highest simulated inductance and capacitance responses with the best signal strength and sensitivity. Moreover, experiments have been conducted to determine the relationship between sensor's impedance and water contamination due to nitrate and sulphate. The sensors have been tested with added distilled water with different concentrations of nitrate and sulphate to observe the system performance. Experimental results show that the best sensor is the star array planar electromagnetic sensor. Artificial Neural Networks (ANN) is used to classify different levels of nitrate and sulphate contaminations in water sources. The impedance of star array planar electromagnetic sensors was derived to decompose by Wavelet Transform (WT). Classification of WT has been applied to extract output signal features. These features are fed into ANN to classify different nitrate and sulphate concentration levels in water. The model is capable of distinguishing contaminants concentration level in the presence of other types of contaminants with a Root Mean Square Error (RMSE) of 0.0132 with 98.68% accuracy.

ABSTRAK

Kerja ini membincangkan penghasilan tiga jenis penderia berasaskan susunan penderia elektromagnetik satah untuk pemantauan alam sekitar. Tiga jenis susunan penderia telah dicadangkan: selari, bintang, dan delta. Pemodelan dan simulasi terhadap semua jenis susunan penderia telah dijalankan untuk mengira nilai galangan penderia. Tahap pencemaran dalam simulasi boleh diubah dengan menukar nilai parameter elektrikal pada domain sekeliling model penderia yang mewakili pencemaran air. Keputusan simulasi menunjukkan persetujuan dengan pola eksperimen. Susunan bintang telah menunjukkan nilai tindakbalas simulasi yang tinggi terhadap induktor dan kapasitor di samping mempunyai nilai kekuatan isyarat dan sensitiviti yang terbaik. Tambahan pula, eksperimen telah dijalankan untuk menentukan hubungkait antara galangan penderia dan air yang tercemar dengan nitrat dan sulfat. Penderia ini telah diuji dengan kemasukan air suling yang mempunyai kelarutan nitrat dan sulfat yang berbeza untuk mengenalpasti prestasi sistem. Keputusan eksperimen menunjukkan penderia terbaik adalah penderia satah elektromagnetik dengan susunan bintang. Rangkaian Neural Buatan (ANN) digunakan untuk mengklasifikasikan tahap pencemaran nitrat dan sulfat di dalam sumber air. Nilai galangan penderia satah elektromagnetik bintang telah diterbitkan untuk diuraikan oleh Penjelmaan Wavelet (WT). Pengasingan WT telah diaplikasikan untuk mengakstrak ciri-ciri pada isyarat keluaran. Ciri-ciri isyarat keluaran dimasukkan kepada ANN untuk pengkelasan tahap pencemaran nitrat dan sulfat yang berbeza di dalam air. Model ini mampu membezakan tahap kelarutan pencemaran dengan kehadiran bahan pencemaran lain sebanyak 0.0132 Ralat Punca Min Kuasa Dua (RMSE) dengan ketepatan sebanyak 98.68%.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

FIA	-	Flow Injection Analysis
ICA	-	Independent Component Analysis
WT	-	Wavelet Transform
ANN	-	Artificial Neural Network
FEM	-	Finite Element Method
ppm	-	Part per million
metHb	-	Methaheamoglobin
oxyHb	-	Oxygenheamoglobin
ISE	-	Ion Selective Electrode
PVC	-	Polyvine
PTFE	-	Polytetrafluoroethylene
CMC	-	Carboxymethylcellulose
CPE	-	Carbon Paste Electrode
PCA	-	Principle Component Analysis
KPCA	-	Kernal Principle Component Analysis
IC	-	Independent Component
PDF	-	Probabily Density Function
fastICA	-	Fast-point algorithm
FFNN	-	Feed Forward Neural Network
RNN	-	Recurrent Neural Network
MLP	-	Multilayer Perceptron
SMD	-	Surface Mount Resistor
PCB	-	Printed-on Circuit Board
FGMRES	-	Flexible Generalized Minimum Residual
PC	-	Personal Computer
RMS	-	Relative Mean Square

BP	-	Back Propogation
MSE	-	Mean Square Error
CWT	-	Continuous Wavelet Transform
RMSE	-	Relative Mean Square Error
LM	-	Local Minima
MEMS	-	Micro Electro Mechanical System

LIST OF SYMBOLS

km^3	-	Cubic kilometre
mg/L	-	Milligram per litre
mg/kg	-	Milligram per kilogram
Fe^{2+}	-	Iron (II) ion
Fe^{3+}	-	Iron (III) ion
NO_2^-	-	Nitrate ion
NO_3^-	-	Nitrite ion
H^+	-	Hydrogen ion
Fe_2O_3	-	Iron (II) oxide
CoO	-	Cobalt oxide
x_i	-	Input for neural network
w_{ji}	-	Weight in the neuron
A_j	-	Activation function
O_j	-	Output function
d_j	-	Desired output value
D_j	-	Error function
S_1	-	Sensor S_1
S_2	-	Sensor S_2
S_3	-	Sensor S_3
R_1	-	Resistor for S_1
R_2	-	Resistor for S_2
R_3	-	Ressitor for S_3
$3D$	-	Three dimension
σ	-	Electrical conductivity
ε_r	-	Relative permittivity
μ_r	-	Relative permeability
^oK	-	Degree Kelvin
atm	-	Atmospheric pressure

J	-	Current density
E	-	Electric field intensity
J_e	-	External current density
B	-	Magnetic field density
A	-	Magnetic vector potentials
V	-	Electric scalar potential of conductor
I	-	Induced current
S	-	Surface
dS	-	Surface element of the surface S
$V_{induced}$	-	Induced voltage across the sensor
N	-	Number of turns in the conductor
E_x	-	Electrical fields for x component
E_y	-	Electrical fields for y component
E_z	-	Electrical fields for z component
i_x	-	Current direction at x
i_y	-	Current direction at y
i_z	-	Current direction at z
A_i	-	Cross sectional area at the respective i^{th} element
m^2	-	Metre square
I_o	-	Current through terminal
V_{S1}	-	Voltage across the sensor S_1
V_{S2}	-	Voltage across the sensor S_2
V_{S3}	-	Voltage across the sensor S_3
V_1	-	Voltage across the source terminal
I_1	-	Current that flow through sensor S_1
I Vs. U	-	Voltage different across two point
L_{S1}	-	Inductance for sensor S_1
w_m	-	Magnetic energy stored in the system
C_{S1}	-	Capacitance value for sensor S_1
f	-	Operating frequency
$X_{total,1}$	-	Total imaginary of impedance for sensor S_1
$t_{samplerate}$	-	Sampling time
F_n	-	Fourier Transform
f_k	-	Data point
$f_{desiredfrequency}$	-	Desired frequency for the respective sample

y	-	Weight of the sample in gram
x	-	The desired ppm value
$Z\%$	-	Impedance sensitivity
$(Z_{total,S})_{sample}$	-	Impedance of the test sample
$(Z_{total,S})_{distilled}$	-	Impedance of the distilled water
O	-	Output of the network
T	-	Target output
t	-	time
α	-	Rate of learning
g	-	Gradient vector
w_t	-	Current weight matrix
a	-	scale
b	-	translation
KNO_3	-	Potassium nitrate
K_2SO_4	-	Potassium sulphate
$\%Z''$	-	Normalized second derivative of impedance of sensor
$A4$	-	Approximation at level 4
$D3$	-	Details at level 3
$D1$	-	Details at level 1

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research Background

The freshwater resources in the world are approximately 2.53% of the world water sources [1]. From these freshwater, only 29.9% and 0.29% came from ground water and freshwater respectively for daily life activities. Clean water is a basic necessity for human beings to survive. Clean water is a ground or fresh water that's been treated. Humans need water for cooking, sports, recreation, etc. Meanwhile, other wildlife such as fish and shrimp depend on clean water for survival. Food sources such as fish that come from good sources can help people to get a good meal that contains proteins and other beneficial nutrients which are needed by the body.

In a normal water cycle where water is free from contaminants, water that falls as rain is absorbed by soil and is used by plants to continue blooming green. Besides, the rain water will continue to flow into the nearest body of water sources. Reservoir water such as rivers, seas and lakes would evaporate by the heat of the hot sun into the sky and will fall back into the earth as rain when the time comes. This process will be repeated and continued. Due to human civilization, the main stream and others reservoir water could be contaminated by foreign substances.

The human civilization process will keep moving forward which makes human life become more sophisticated, comfortable, easier and simple. Human civilizations resulted in the industrial, agricultural and farm areas expanding tremendously [2]. Expansion in those areas will increase the probability of water being contaminated by foreign substances such as nitrate, sulphate, nickel, phosphorus and zinc. These foreign substances come from the unused or waste product of the industry.

Foreign substances such as nitrate, nickel and sulphate could cause adverse effect to human health. The problem is compounded by the fact that these substances could not be seen by the eye. Many researchers have created devices that could detect the presence of these contaminated substances in water [3].

One of these device is known as the planar electromagnetic sensor which can calibrate the impedance of the water [4]. Different types of contaminants would have different impedance values. These are due to the different electrical properties of each substances.

However, the problem with the planar electromagnetic sensor is that it takes a lot of time to acquire data. Due to this disadvantage, this research aims to develop a planar electromagnetic sensor with different array configurations which could reduce the time taken for the sensor to perform measurement.

1.2 Problem Statement

Reservoir water is always exposed to the unwanted or foreign substances resulting from the development in industrial and agricultural sector. Moreover, livestock also could contribute to the existence of sediment in natural water sources. Naturally, nitrate and sulphate are present in natural water resources. The presence of excessive unwanted substances such as nitrate, sulphate, phosphorus, nickel and zinc could cause adverse effect on human health. Hence, it is important to monitor and maintain the concentration of the unwanted foreign substances within the permitted amount.

Many researchers have come out with various solutions to monitor and detect the presence of unwanted material [3] as summarized in Table 1.1. However, the existing detection methods required tedious working steps and requiring meticulous lab working procedures [5]. In addition, the existing methods required preparation of extra reagent and consume a lot of time [6]. Furthermore, the test sample itself might be contaminated by unwanted substances during the preparation or testing of the sample [7].

Table 1.1: Advantages and disadvantages of available detection methods

Detection Methods	Advantage	Disadvantage
Potentiometry [83]	Provide high pH range and high sensitivity	Exposed toward emmision of harzadous gases
Ion Chromatography [77]	Provide accurate and high realibility	Bulky and expensive equipments
Electrochemical [90-91]	Simple and small structure	Inaccurate result due to the presence of other type of ions
Biosensor [98]	Cheap and portable	Need controlled working environment
Flow Injection Analysis (FIA) [107]	Give fast response	High maintenance during breakdown

There have been a lot of concern developing a sensing system that can overcome the problem of detection methods as listed in Table 1.1. Therefore, the main problem is how to create a system that can detect nitrate and sulphate that has a better accuracy, low-cost and can produce a rapid measurement?

Looking at the disadvantages of other detection methods, the planar electromagnetic sensor has been used in determining the amount of contaminant in the water. Each contaminant has a unique criteria where different contaminant contain different electrical properties. This property makes the detection caused by induction of both electric and magnetic fields become possible. Planar electromagnetic sensors can be divided into two types: inductive and capacitive. Inductive and capacitive types of planar electromagnetic sensors occurred when either the magnetic or electric field dominated the sensing area. The capacitive type sensor of planar electromagnetic are widely used in industry such as measurement of the level of pulp moisture [8], monitoring the growth of immobilized bacteria [9], human's food inspection [10], and skin water content that determine the human health status [11]. On the other hand, the inductive type sensors have been used as a proximity and displacement sensor [12], and inspection of different integrity of each coin [13]. Hence, it can be shown that capacitive and inductive type sensors are responsive to non-metal and metal, respectively.

By combining both types of inductive and capacitive sensors, it can estimate the relationship between sensor impedance with material under test electrical properties. Yunus *et. al.* [14] used a planar eletromagnetic sensor to estimate nitrate contamination in natural water sources. However, the planar electromagnetic sensor only provided one output channel.

Besides, previous planar electromagnetic used Independent Component Analysis (ICA) as a tool to estimate the contamination obtained from the sensor [15]. ICA is reported as a powerful tool due to its capability in reducing the dimension of the data during the analysis. The main problem in the later work was that the measurement had to be repeated many times to provide a sufficient data set for the analysis based on ICA. Therefore, three types of sensor arrays, were suggested in this thesis: parallel, star, and delta. Furthermore, the water samples with sensor arrays outputs dependency on the electrical properties of the water samples needs to be investigated thorugh simulation and experimental works.

In this work, the outputs of a planar electromagnetic sensors array were observed and analyzed after testing it with different types of water samples at different concentrations of nitrate and sulphate. It is learnt from the outputs that sensitivity shows limited diferentiation between different concentrations of nitrate and sulphate. Therefore, the output parameters were derived to decompose by Wavelet Transform (WT) to obtain further informations from the sensor array outputs in order to provide sufficient inputs for the Artificial Neural Network. The energy and mean features of decomposed signals were extracted and used as inputs for an Artificial Neural Network (ANN) model.

A different approach is used to estimate using ANN method. To complete the ANN model in estimating nitrate and sulphate in water source, the following steps were required; training, validation, and testing. It is important to see the effect of estimating nitrate and sulphate without ANN. Therefore, the classification process is repeated without ANN. Hence, the importance of ANN in estimating nitrate and sulphate is proven by comparing the results of classification with and without ANN.

1.3 Research Objectives

By looking at the advantages and disadvantages of other detection methods, this project aims to achieve the main objective to design and fabricate novel planar electromagnetic sensors array based on the combination of meander and interdigital elements for the application of contamination detection in natural water sources. In order to achieve the main objective, the following objectives have been established:-

1. To perform modelling and simulation of the novel planar electromagnetic array sensors based on the finite element method (FEM).
2. To complete the characterization of the sensor arrays and determination of the best sensor.
3. To carry out nitrate and sulphate estimation using the best planar electromagnetic sensor array and Artificial Neural Network (ANN) method.

1.4 Significance of the Study

This research focuses on the detection of contaminants such as nitrate and sulphate in natural water sources. The concern on water quality has received a lot of attention nowadays due to the consequence of bad health effect caused by the low quality of water consumed. Sources of water contaminant have become broad due to the human civilization. An increase in industrial and agriculture areas has caused a significant increase in water contaminants such as nitrate and sulphate. The high concentration of nitrate and sulphate in water could cause adverse effect to both human and its surrounding environments. Due to this awareness a lot of research work has been done by various researchers from all over the world to estimate the concentration of the contaminant. In order to make the detection processes become simpler and easier, the contaminant detectors have features like low-cost, convenient and suitable for in-situ measurement.

1.5 Scope of Study

This work investigated the water contaminant detection method using a planar electromagnetic sensor with different array configurations known as parallel, star and delta. The study involved simulation and experimental stages, where the simulation is used to verify the experimental result. Apparatus such as personal computer, function generator, oscilloscope, and beaker was used to carry out the study. Besides, the COMSOL Multiphysic 4.2 and Lab*View* software also used to achieve the research objectives. In this study, the impedance of each sensor was calculated in which the impedance value will determine the concentration level of each contaminant. In addition, each contaminant would have different impedance values based on its own electrical properties. Different concentrations of the same contaminant would also give different impedance values. The impedance of controlled water samples will be matched with the impedance of water from the nearest river to determine the content of river water.

1.6 Organization of the Thesis

This thesis is organized into six chapters starting with the introduction of research background up to the analysis and conclusion together with the future work on planar electromagnetic sensor arrays. Chapter 2 describes the literature review for planar electromagnetic sensor array which include the source of contamination, detection method, working principles, designed array and analysis. The sensor array was modelled and simulated using COMSOL Multiphysic as discussed in Chapter 3.

In addition, the results obtained from simulated modelling are analyzed at the end of Chapter 3. Futhermore, Chapter 3 also discuss the classification of signals using Artificial Neural Network (ANN). In Chapter 4, the experimental setup is illustrated in details. The experimental results are also discussed and analyzed. Chapter 5 expounds the application of analysis tool known as ANN to classify the output of the sensor's impedance. Finally, the conclusion of current work and future work are presented in Chapter 6.

REFERENCES

[1] S. L. Postel, G. C. Daily, and P. R. Ehrlich (1996). "Human appropriation of renewable fresh water,". *Science-AAAS-Weekly Paper Edition.* Vol. 271, pp. 785-787.

[2] S. Wirsenius, C. Azar, and G. Berndes (2010). "How much land is needed for global food production under scenarios of dietary changes and livestock productivity increases in 2030?,". *Agricultural Systems.* Vol. 103, pp. 621-638.

[3] S. D. Richardson and T. A. Ternes (2011). "Water analysis: emerging contaminants and current issues,". *Analytical chemistry.* Vol. 83, pp. 4614-4648.

[4] M. M. Yunus and S. Mukhopadhyay (2011). "Development of planar electromagnetic sensors for measurement and monitoring of environmental parameters,". *Measurement Science and Technology.* Vol. 22, p. 025107.

[5] M. Gómez, M. Gómez-Ramos, A. Agüera, M. Mezcua, S. Herrera, and A. Fernández-Alba (2009). "A new gas chromatography/mass spectrometry method for the simultaneous analysis of target and non-target organic contaminants in waters,". *Journal of Chromatography A.* Vol. 1216, pp. 4071-4082.

[6] R. B. R. Mesquita, M. T. S. O. B. Ferreira, R. L. A. Segundo, C. F. C. P. Teixeira, A. A. Bordalo, and A. O. S. S. Rangel (2009). "Development of a sequential injection system for the determination of nitrite and nitrate in waters with different salinity: application to estuaries in NW Portugal,". *Analytical Methods.* Vol. 1, pp. 195-202.

[7] I. Sirés and E. Brillas (2012). "Remediation of water pollution caused by pharmaceutical residues based on electrochemical separation and degradation technologies: a review,". *Environment international.* Vol. 40, pp. 212-229.

[8] K. Sundara-Rajan, L. Byrd, and A. V. Mamishev (2004). "Moisture content estimation in paper pulp using fringing field impedance spectroscopy,". *Sensors Journal, IEEE.* Vol. 4, pp. 378-383.

[9] S. M. Radke and E. C. Alocilja (2004). "Design and fabrication of a microimpedance biosensor for bacterial detection,". *Sensors Journal, IEEE.* Vol. 4, pp. 434-440.

[10] A. Mohd Syaifudin, S. Mukhopadhyay, and P. Yu (2012). "Modelling and fabrication of optimum structure of novel interdigital sensors for food inspection,". *International Journal of Numerical Modelling: Electronic Networks, Devices and Fields.* Vol. 25, pp. 64-81.

[11] N. Sekiguchi, T. Komeda, H. Funakubo, R. Chabicovsky, J. Nicolics, and G. Stangl (2001). "Microsensor for the measurement of water content in the human skin,". *Sensors and Actuators B: Chemical.* Vol. 78, pp. 326-330.

[12] K. D. Anim-Appiah and S. M. Riad (1997). "Analysis and design of ferrite cores for eddy-current-killed oscillator inductive proximity sensors,". *IEEE Transactions on Magnetics.* Vol. 33, pp. 2274-2281.

[13] S. Karunanayaka, C. Gooneratne, S. Mukhopadhyay, and G. S. Gupta (2006). "A planar electromagnetic sensors aided non-destructive testing of currency coins,". *NDT.net.* Vol. 11, no. 10.

[14] M. A. M. Yunus and S. C. Mukhopadhyay (2011). "Novel planar electromagnetic sensors for detection of nitrates and contamination in natural water sources,". *IEEE Sensors Journal.* Vol. 11, pp. 1440-1447.

[15] M. A. M. Yunus, S. C. Mukhopadhyay, and S. Ibrahim (2012). "Planar electromagnetic sensor based estimation of nitrate contamination in water sources using independent component analysis,". *IEEE Sensors Journal.* Vol. 12, pp. 2024-2034.

[16] P. H. Gleick (2014). "The World's Water Volume 8: The Biennial Report on Freshwater Resources,". *Island Press. Washington DC.* Vol. 8.

[17] P. H. Gleick and M. Palaniappan (2010). "Peak water limits to freshwater withdrawal and use,". *Proceedings of the National Academy of Sciences.* Vol. 107, pp. 11155-11162.

[18] R. Ghosh (2014). "50 FAQs on Water Pollution: know all about water pollution and do your bit to limit it,". *1st Edition, TERI Press*. New Delhi.

[19] A. G. Heath (1995). "*Water pollution and fish physiology*,". CRC press.

[20] J. Zhang, Y. Zhou, and J. Wang (2009). "Pay Attention to Rural Non-Point Source Pollution, Guarantee the Security of Drinking Water,". in *3rd International Conference on Bioinformatics and Biomedical Engineering.. ICBBE 2009*. 11-13 June 2009. Beijing, pp. 1-4.

[21] W. Subra and J. Waters (1996). "Non point source pollution," in *International Geoscience and Remote Sensing Symposium, IGARSS'96:Remote Sensing for a Sustainable Future. 27-31 May* 1996. Lincoln NE, pp. 2231-2233.

[22] X. Zhai, Y. Zhang, X. Wang, J. Xia, and T. Liang (2014). "Non-point source pollution modelling using Soil and Water Assessment Tool and its parameter sensitivity analysis in Xin'anjiang catchment, China,". *Hydrological Processes.* Vol. 28, pp. 1627-1640.

[23] I. Wesström, A. Joel, and I. Messing (2014). "Controlled drainage and subirrigation–A water management option to reduce non-point source pollution from agricultural land,". *Agriculture, Ecosystems & Environment. in Press, accepted on 29 March 2014.*

[24] S. S. Rabotyagov, A. M. Valcu, and C. L. Kling (2013). "Reversing Property Rights: Practice-Based Approaches for Controlling Agricultural Nonpoint-source Water Pollution When Emissions Aggregate Nonlinearly,". *American Journal of Agricultural Economics.* Vol. 96(2), pp. 397-419.

[25] D.-F. Huang, W.-H. Li, L.-M. Wang, X.-J. Lin, P. Fan, and X.-X. Qiu (2014). "Study on water and fertilizer managements and evaluation of nitrogen and phosphorus non-point source pollution from paddy field,". *Image Processing for Cinema.* Vol. 4, p. 335.

[26] J. Pan, J. A. Plant, N. Voulvoulis, C. J. Oates, and C. Ihlenfeld (2010). "Cadmium levels in Europe: implications for human health,". *Environmental geochemistry and health.* Vol. 32(1), pp. 1-12.

[27] C. He, L. Zhang, C. DeMarchi, and T. E. Croley II (2014). "Estimating point and nonpoint sources pollution loadings in the Saginaw Bay Watersheds,". *Journal of Great Lakes Research.* Vol. 40, p.p. 11-17.

[28] N. Arif and R. Afroz (2014). "Electrical and Electronic Waste Management–A Case Study in University of Duhok, Iraq,". *Journal of Economics and Sustainable Development.* Vol. 5, pp. 21-27.

[29] Y. H. Teo (2014). "Water services industry reforms in Malaysia," *International Journal of Water Resources Development.* Vol. 30, pp. 1-10, 2014.

[30] G. Liste, R. Kirkden, and D. Broom (2013). "A commercial trial evaluating three open water sources for farmed ducks: effects on water usage and water quality,". *British poultry science.* Vol. 54, pp. 24-32.

[31] H. Steinfeld, C. De Haan, and H. Blackburn (1997). "Livestock-environment interactions,". *Issues and options. Report of the Commission Directorate General for Development. Fressingfield, UK, WREN Media. pp56.*

[32] A. J. Rahman (2014). "Water Pollution Control Policy: Addressing Non-Point Source Pollution,". *Student Pulse.* Vol. 6, no. 3, pp. 1-3.

[33] A. V. Marenich, C. J. Cramer, and D. G. Truhlar (2009). "Universal solvation model based on solute electron density and on a continuum model of the solvent defined by the bulk dielectric constant and atomic surface tensions,". *The Journal of Physical Chemistry B.* Vol. 113, pp. 6378-6396.

[34] C. Franche, K. Lindström, and C. Elmerich (2009). "Nitrogen-fixing bacteria associated with leguminous and non-leguminous plants,". *Plant and soil.* Vol. 321, pp. 35-59.

[35] G. Chen, X. Cao, C. Song, and Y. Zhou (2010). "Adverse effects of ammonia on nitrification process: the case of Chinese shallow freshwater lakes,". *Water, Air, & Soil Pollution.* Vol. 210, pp. 297-306.

[36] R. Alvarez and H. Steinbach (2009). "A review of the effects of tillage systems on some soil physical properties, water content, nitrate availability and crops yield in the Argentine Pampas,". *Soil and Tillage Research.* Vol. 104, pp. 1-15.

[37] S. Krause, L. Heathwaite, A. Binley, and P. Keenan (2009). "Nitrate concentration changes at the groundwater-surface water interface of a small Cumbrian river,". *Hydrological Processes.* Vol. 23, pp. 2195-2211.

[38] I. Castro-Quezada, B. Román-Viñas, and L. Serra-Majem (2014). "The Mediterranean Diet and Nutritional Adequacy: A Review,". *Nutrients.* Vol. 6, pp. 231-248.

[39] P. Santamaria (2006). "Nitrate in vegetables: toxicity, content, intake and EC regulation,". *Journal of the Science of Food and Agriculture.* Vol. 86, pp. 10-17.

[40] V. Kapil, A. B. Milsom, M. Okorie, S. Maleki-Toyserkani, F. Akram, F. Rehman, *et al.* (2010). "Inorganic nitrate supplementation lowers blood pressure in humans role for nitrite-derived NO,". *Hypertension.* Vol. 56, pp. 274-281.

[41] A. H. Liu, C. P. Bondonno, K. D. Croft, I. B. Puddey, R. J. Woodman, L. Rich, *et al.*, "Effects of a nitrate-rich meal on arterial stiffness and blood pressure in healthy volunteers," *Nitric Oxide*, vol. 35, pp. 123-130, 2013.

[42] N. G. Hord (2011). "Dietary nitrates, nitrites, and cardiovascular disease,". *Current atherosclerosis reports.* Vol. 13, pp. 484-492.

[43] A. J. Webb, N. Patel, S. Loukogeorgakis, M. Okorie, Z. Aboud, S. Misra, *et al.* (2008). "Acute blood pressure lowering, vasoprotective, and antiplatelet properties of dietary nitrate via bioconversion to nitrite,". *Hypertension.* Vol. 51, pp. 784-790.

[44] R. J. Woodman and G. F. Watts (2003). "Measurement and application of arterial stiffness in clinical research: focus on new methodologies and diabetes mellitus,". *Medical science monitor: international medical journal of experimental and clinical research.* Vol. 9(5), pp. RA81-RA89.

[45] T. E. Ingram, A. G. Pinder, D. M. Bailey, A. G. Fraser, and P. E. James (2010). "Low-dose sodium nitrite vasodilates hypoxic human pulmonary vasculature

by a means that is not dependent on a simultaneous elevation in plasma nitrite,". *American Journal of Physiology-Heart and Circulatory Physiology,* Vol. 298(2), p. H331-H339.

[46] V. E. Nossaman, B. D. Nossaman, and P. J. Kadowitz (2010). "Nitrates and nitrites in the treatment of ischemic cardiac disease,". *review in Cardiology.* Vol. 18(4), pp. 190-197.

[47] L. Knobeloch, B. Salna, A. Hogan, J. Postle, and H. Anderson (2000). "Blue babies and nitrate-contaminated well water,". *Environmental Health Perspectives.* Vol. 108(4), pp. 675-678.

[48] T. Tamme, M. Reinik, and M. Roasto (2009). "Nitrates and nitrites in vegetables: occurrence and health risks,". *Bioactive foods in promoting health: fruits and vegetables. Academic Press.* pp. 307-321.

[49] Ö. Özdestan and A. Üren (2012). "Nitrate and Nitrite Contents of Baby Foods," *Academic Food Journal/Akademik GIDA.* Vol. 10, pp. 11-18.

[50] D. B. D. Elias, L. B. d. S. Rocha, M. B. Cavalcante, A. M. Pedrosa, I. C. B. Justino, and R. P. Gonçalves (2012). "Correlation of low levels of nitrite and high levels of fetal hemoglobin in patients with sickle cell disease at baseline,". *Revista brasileira de hematologia e hemoterapia.* Vol. 34, pp. 265-269.

[51] W. Lijinsky (1999). "Nitroso compounds in the diet," *Mutation Research/Genetic Toxicology and Environmental Mutagenesis.* Vol. 443, pp. 129-138.

[52] A. Migowska-Calik, Gom, M. ołka-Pawlicka, J. Uradziński, and T. Lachowicz (2014). "Specificity of the production of traditional meat products and their safety using polish traditional cured meat products as example,". *African Journal of Microbiology Research.* Vol. 8, pp. 1050-1059.

[53] World Health Organization (2010). "IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Ingested Nitrate and Nitrite, and Cyanobacterial Peptide Toxins,". *International Agency for Research on Cancer.* Lyon, France, Vol. 94.

[54] J. O. Lundberg and M. Govoni (2004). "Inorganic nitrate is a possible source for systemic generation of nitric oxide,". *Free Radical Biology and Medicine.* Vol. 37, pp. 395-400.

[55] C. S. Bruning-Fann and J. Kaneene (1993). "The effects of nitrate, nitrite and N-nitroso compounds on human health: a review," *Veterinary and human toxicology.* Vol. 35, pp. 521-538.

[56] A. P. Keszei, R. A. Goldbohm, L. J. Schouten, P. Jakszyn, and P. A. van den Brandt (2013). "Dietary N-nitroso compounds, endogenous nitrosation, and the risk of esophageal and gastric cancer subtypes in the Netherlands Cohort Study,". *The American journal of clinical nutrition.* Vol. 97, pp. 135-146.

[57] M. H. Ward and L. López-Carrillo (1999). "Dietary factors and the risk of gastric cancer in Mexico City,". *American journal of epidemiology.* Vol. 149, pp. 925-932.

[58] E. Denova-Gutiérrez, R. U. Hernández-Ramírez, and L. López-Carrillo (2014). "Dietary Patterns and Gastric Cancer Risk in Mexico,". *Nutrition and cancer.* Vol. 66, pp. 369-376.

[59] A. Omstedt, M. Edman, L. G. Anderson, and H. Laudon (2010). "Factors influencing the acid–base (pH) balance in the Baltic Sea: a sensitivity analysis,". *Tellus B.* Vol. 62, pp. 280-295.

[60] A. Matilainen, M. Vepsäläinen, and M. Sillanpää (2010). "Natural organic matter removal by coagulation during drinking water treatment: A review,". *Advances in Colloid and Interface Science.* Vol. 159, pp. 189-197.

[61] C. Li, Y. Yao, and L. Wang (2010). "Accelerate Thaumasite Form of Sulfate Attack in Cement-Based Materials by Internal Doping Magnesium Sulfate [j]," *Journal of the Chinese Ceramic Society.* Vol. 7, 010.

[62] S. Alderman (2014). "Rockfish are anxious about climate change too!,". *The Journal of Experimental Biology.* Vol. 217, pp. 1012-1012.

[63] A. Najah, A. El-Shafie, O. Karim, and A. H. El-Shafie (2014). "Performance of ANFIS versus MLP-NN dissolved oxygen prediction models in water quality monitoring,". *Environmental Science and Pollution Research.* Vol. 21, pp. 1658-1670.

[64] F. Cook, W. Hicks, E. Gardner, G. D. Carlin, and D. Froggatt (2000). "Export of acidity in drainage water from acid sulphate soils,". *Marine Pollution Bulletin.* Vol. 41, pp. 319-326.

[65] H. Ding, S. Yao, and J. Chen (2014). "Authigenic pyrite formation and re-oxidation as an indicator of an unsteady-state redox sedimentary environment: Evidence from the intertidal mangrove sediments of Hainan Island, China,". *Continental Shelf Research.* Vol. 78, pp. 85-99.

[66] D. K. Nordstrom (1982). "Aqueous pyrite oxidation and the consequent formation of secondary iron minerals,". *Acid sulfate weathering.* pp. 37-56.

[67] G. Fraser, R. Callinan, and L. Calder (1992). "Aphanomyces species associated with red spot disease: an ulcerative disease of estuarine fish from eastern Australia,". *Journal of Fish Diseases.* Vol. 15, pp. 173-181.

[68] S. Kamali, B. Gérard, and M. Moranville (2003). "Modelling the leaching kinetics of cement-based materials—influence of materials and environment,". *Cement and Concrete Composites.* Vol. 25, pp. 451-458.

[69] F. Adenot and M. Buil (1992). "Modelling of the corrosion of the cement paste by deionized water,". *Cement and Concrete Research.* Vol. 22, pp. 489-496.

[70] P. Feng, C. Miao, and J. W. Bullard (2014). "A Model of Phase Stability, Microstructure and Properties During Leaching of Portland Cement Binders,". *Cement and Concrete Composites.* Vol. 49, pp. 9-19..

[71] A. Skaropoulou, G. Kakali, and S. Tsivilis (2012). "Thaumasite form of sulfate attack in limestone cement concrete: The effect of cement composition, sand type and exposure temperature,". *Construction and Building Materials.* Vol. 36, pp. 527-533.

[72] K. Sotiriadis, E. Nikolopoulou, S. Tsivilis, A. Pavlou, E. Chaniotakis, and R. Swamy (2013). "The effect of chlorides on the thaumasite form of sulfate attack of limestone cement concrete containing mineral admixtures at low temperature,". *Construction and Building Materials.* Vol. 43, pp. 156-164.

[73] S. U. Al-Dulaijan, M. Maslehuddin, M. Al-Zahrani, A. Sharif, M. Shameem, and M. Ibrahim (2003). "Sulfate resistance of plain and blended cements exposed to varying concentrations of sodium sulfate,". *Cement and Concrete Composites.* Vol. 25, pp. 429-437.

[74] E. Rozière, A. Loukili, R. El Hachem, and F. Grondin (2009). "Durability of concrete exposed to leaching and external sulphate attacks,". *Cement and Concrete Research.* Vol. 39, pp. 1188-1198.

[75] A. M. Ramezanianpour and R. D. Hooton (2013). "Thaumasite sulfate attack in Portland and Portland-limestone cement mortars exposed to sulfate solution,". *Construction and Building Materials.* Vol. 40, pp. 162-173.

[76] P. Gebauer, M. Deml, P. Boček, and J. Janak (1983). "Determination of nitrate, chloride and sulphate in drinking water by capillary free-zone electrophoresis,". *Journal of Chromatography A.* Vol. 267, pp. 455-457.

[77] J. Hern, G. Rutherford, and G. Vanloon (1983). "Determination of chloride, nitrate, sulphate and total sulphur in environmental samples by single-column ion chromatography,". *Talanta.* Vol. 30, pp. 677-682.

[78] J. Liu, X. N. Ji, Q. K. Ren, S. S. Ai, L. J. Wan, and D. J. Bian (2014). "Determination of Nitrate in Water by HPLC,". *Applied Mechanics and Materials.* Vol. 448, pp. 406-408.

[79] T. Madasamy, M. Pandiaraj, M. Balamurugan, K. Bhargava, N. K. Sethy, and C. Karunakaran (2014). "Copper, zinc superoxide dismutase and nitrate reductase coimmobilized bienzymatic biosensor for the simultaneous determination of nitrite and nitrate,". *Biosensors and Bioelectronics.* Vol. 52, pp. 209-215.

[80] B. Schnetger and C. Lehners (2014). "Determination of nitrate plus nitrite in small volume marine water samples using vanadium (III) chloride as a reduction agent,". *Marine Chemistry*. Vol. 160, pp. 91-98.

[81] M. Santhiago, C. S. Henry, and L. T. Kubota (2014). "Low cost, simple three dimensional electrochemical paper-based analytical device for determination of p-nitrophenol,". *Electrochimica Acta.* Vol. 130, pp. 771-777.

[82] P. Zeng, X. Xie, Y. Song, R. Liu, C. Zhu, A. Galarneau, *et al.* (2014). "Ion chromatography as highly suitable method for rapid and accurate determination of antibiotic fosfomycin in pharmaceutical wastewater,". Water and Science Technology. Vol. 69, pp. 2014-2022.

[83] C. Wardak (2014). "Solid Contact Nitrate Ion-Selective Electrode Based on Ionic Liquid with Stable and Reproducible Potential,". *Electroanalysis.* Vol. 26, pp. 864-872.

[84] B. Paczosa-Bator, L. Cabaj, M. Raś, B. Baś, and R. Piech (2014). "Potentiometric Sensor Platform Based on a Carbon Black Modified Electrodes,". *International Journal Electrochemical Science.* Vol. 9, pp. 2816-2823.

[85] O. Galović, M. Samardžić, S. Petrušić, and M. Sak-Bosnar (2014). "A New Sensing Material for the Potentiometric Determination of Anionic Surfactants in Commercial Products,". *International Journal Electrochemical Science..* Vol. 9, pp. 3802-3818.

[86] S. Yang and M. E. Meyerhoff (2013). "Study of Cobalt (III) Corrole as the Neutral Ionophore for Nitrite and Nitrate Detection via Polymeric Membrane Electrodes,". *Electroanalysis.* Vol. 25, pp. 2579-2585.

[87] S. Firouzabadi, I. Razavipanah, R. Zhiani, M. Ghanei-Motlagh, and M. R. Salavati (2013). "Sulfate-selective electrode based on a bis-thiourea ionophore,". *Monatshefte für Chemie-Chemical Monthly.* Vol. 144, pp. 113-120.

[88] S. Udkhao, A. Wongchaisuwat, and L. Meesuk (2013). "ZnS-Intercalated Montmorillonite: A Low Cost Potentiometric Sensor,". *Advanced Materials Research.* Vol. 787, pp. 291-295.

[89] R. Younes (2014). "Review Of Recent Trends in Gas Sensing Technologies and their Miniaturization Potential,". *Sensor Review.* Vol. 34, pp. 4-4.

[90] C. Ait Ramdane-Terbouche, A. Terbouche, S. Djebbar, and D. Hauchard (2014). "Electrochemical sensors using modified electrodes based on copper complexes formed with Algerian humic acid modified with ethylenediamine

or triethylenetetramine for determination of nitrite in water,". *Talanta.* Vol. 119, pp. 214-225.

[91] J. Wang, D. Zhao, Y. Zhang, J. Li, and C. Xu (2014). "A highly sensitive sensor for the detection of nitrite based on a nanoporous Fe 2 O 3–CoO composite,". *Analytical Methods.* Vol. 6, pp. 3147-3151.

[92] A. Vinu Mohan, K. Aswini, and V. Biju (2014). "Electrochemical codeposition of gold particle–poly (2-(2-pyridyl) benzimidazole) hybrid film on glassy carbon electrode for the electrocatalytic oxidation of nitric oxide,". *Sensors and Actuators B: Chemical.* Vol. 196, pp. 406-412.

[93] D. Yu, D. Yong, and S. Dong (2013). "Toxicity detection of sodium nitrite, borax and aluminum potassium sulfate using electrochemical method,". *Journal of Environmental Sciences.* Vol. 25, pp. 785-790.

[94] A. S. Adekunle, O. A. Arotiba, and B. B. Mamba (2012). "Electrochemical Studies and Sensing of Iodate, Periodate and Sulphite Ions at Carbon Nanotubes/Prussian Blue Films Modified Platinum Electrode,". *International Journal of Electrochemical Science.* Vol. 7, pp. 8503-8521.

[95] G. Velvizhi, R. K. Goud, and S. Venkata Mohan (2014). "Anoxic bio-electrochemical system for treatment of complex chemical wastewater with simultaneous bioelectricity generation,". *Bioresource technolog.*, Vol. 151, pp. 214-220.

[96] X. Mao, X. Yang, G. C. Rutledge, and T. Alan Hatton (2014). "Ultra-Wide-Range Electrochemical Sensing Using Continuous Electrospun Carbon Nanofibers with High Densities of States,". *ACS applied materials & interfaces.* Vol. 6, pp. 3394-3405.

[97] G. P. Boczkaj, A. Przyjazny, and M. Kaminski (2014). "New procedures for control of industrial effluents treatment processes,". *Industrial & Engineering Chemistry Research.* Vol. 53(4), pp. 1503-1514.

[98] E. Khaled, M. S. Kamel, H. Hassan, H. Abdel-Gawad, and H. Y. Aboul-Enein (2014). "Performance of a portable biosensor for the analysis of ethion residues," *Talanta.* Vol. 119, pp. 467-472.

[99] O. A. Sadik, S. K. Mwilu, and A. Aluoch (2010). "Smart electrochemical biosensors: From advanced materials to ultrasensitive devices,". *Electrochimica Acta.* Vol. 55, pp. 4287-4295.

[100] C. Warwick, A. Guerreiro, and A. Soares (2013). "Sensing and analysis of soluble phosphates in environmental samples: A review,". *Biosensors and Bioelectronics.* Vol. 41, pp. 1-11.

[101] Z. Zhang, S. Xia, D. Leonard, N. Jaffrezic-Renault, J. Zhang, F. Bessueille, *et al.* (2009). "A novel nitrite biosensor based on conductometric electrode modified with cytochrome-c-nitrite reductase composite membrane,". *Biosensors and Bioelectronics.* Vol. 24, pp. 1574-1579.

[102] A. Amine and G. Palleschi (2014). "Phosphate, nitrate, and sulfate biosensors,". *Analytical letters.* Vol. 37, pp. 1-19.

[103] F. Can, S. Korkut Ozoner, P. Ergenekon, and E. Erhan (2012). "Amperometric nitrate biosensor based on Carbon nanotube/Polypyrrole/Nitrate reductase biofilm electrode,". *Materials Science and Engineering: C.* Vol. 32, pp. 18-23.

[104] R. Dubey and S. Upadhyay (2001). "Microbial corrosion monitoring by an amperometric microbial biosensor developed using whole cell of i Pseudomonas sp,". *Biosensors and Bioelectronics.* Vol. 16, pp. 995-1000.

[105] B. Molinero-Abad, M. A. Alonso-Lomillo, O. Domínguez-Renedo, and M. J. Arcos-Martínez (2014). "Sulfite oxidase biosensors based on

tetrathiafulvalene modified screen-printed carbon electrodes for sulfite determination in wine,". *Analytica Chimica Acta.* Vol. 812, pp. 41-44.

[106] C.-L. Zheng, Z.-X. Ji, J. Zhang, and S.-N. Ding (2014). "A fluorescent sensor to detect sodium dodecyl sulfate based on the glutathione-stabilized gold nanoclusters/Poly diallyldimethylammonium chloride system,". *Analyst*. Vol. 139, pp. 3476-3480.

[107] C. Ruiz-Capillas and F. Jiménez-Colmenero (2009). "Application of flow injection analysis for determining sulphites in food and beverages: A review,". *Food chemistry.* Vol. 112, pp. 487-493.

[108] R. B. Mesquita and A. O. Rangel (2009). "A review on sequential injection methods for water analysis,". *Analytica chimica acta.* Vol. 648, pp. 7-22.

[109] Y. Sheiretov, D. Grundy, V. Zilberstein, N. Goldfine, and S. Maley (2009). "MWM-array sensors for in situ monitoring of high-temperature components in power plants,". *IEEE Sensors Journal.* Vol. 9, pp. 1527-1536, 2009.

[110] N. Goldfine (1996). "Near surface material property profiling for determination of SCC susceptibility," in *4th EPRI Balance-of-Plant Heat Exchanger NDE Symposium, WY, June 10-12, 1996*.

[111] Gebbers, Robin, and Viacheslav I. Adamchuk (2010). "Precision agriculture and food security,". *Science* 327. Vol. 5967, pp. 828-831.

[112] A. Salunkhe and M. Chavan (2012). "Estimation of Fat Contents in Milk: A Review.". *International Journal of Electronics Engineering*. Vol. 4 no. 2, pp. 211-215.

[113] P. Barge, P. Gay, V. Merlino, and C. Tortia (2014). "Item-level Radio-Frequency IDentification for the traceability of food products: Application on a dairy product,". *Journal of Food Engineering.* Vol. 125, pp. 119-130.

[114] J. Vanfleteren, M. Gonzalez, F. Bossuyt, Y.-Y. Hsu, T. Vervust, I. De Wolf, *et al.* (2012). "Printed circuit board technology inspired stretchable circuits,". *MRS bulletin.* Vol. 37, pp. 254-260.

[115] M. Norhisam, A. Norrimah, R. Wagiran, R. Sidek, N. Mariun, and H. Wakiwaka (2008). "Consideration of theoretical equation for output voltage of linear displacement sensor using meander coil and pattern guide,". *Sensors and Actuators A: Physical.* Vol. 147, pp. 470-473.

[116] H. Wakiwaka, H. Nishizawa, S. Yanase, and O. Maehara (1996). "Analysis of impedance characteristics of meander coil,". *IEEE Transactions on Magnetics.* Vol. 32, pp. 4332-4334.

[117] H. A. Radi and J. O. Rasmussen (2013). "Faraday’s Law, Alternating Current, and Maxwell’s Equations,". in *Principles of Physics*, ed: Springer, pp. 933-959.

[118] S. Mukhopadhyay, S. D. Choudhury, T. Allsop, V. Kasturi, and G. Norris (2008). "Assessment of pelt quality in leather making using a novel non-invasive sensing approach,". *Journal of biochemical and biophysical methods.* Vol. 70, pp. 809-815.

[119] A. I. Zia, M. S. A. Rahman, S. C. Mukhopadhyay, P.-L. Yu, I. Al-Bahadly, C. P. Gooneratne, *et al.* (2013). "Technique for rapid detection of phthalates in water and beverages,". *Journal of Food Engineering.* Vol. 116, pp. 515-523.

[120] L. Y. Zhao (2013). "Novel Sensor Design and Application for Detection of Dangerous Contaminated Marine Biotoxins,". *Applied Mechanics and Materials.* Vol. 416, pp. 980-984.

[121] S. C. Mukhopadhyay (2013). *Intelligent Sensing, Instrumentation and Measurements.* Vol. 5: Springer.

[122] S. E. Parks, D. E. Irving, and P. J. Milham (2012). "A critical evaluation of on-farm rapid tests for measuring nitrate in leafy vegetables,". *Scientia Horticulturae.* Vol. 134, pp. 1-6.

[123] P. E. Green (2014). *Mathematical tools for applied multivariate analysis*: Academic Press.

[124] K. K. Hall, B. G. Evanshen, K. J. Maier, and P. R. Scheuerman (2014). "Application of Multivariate Statistical Methodology to Model Factors Influencing Fate and Transport of Fecal Pollution in Surface Waters,". *Journal of Environmental Quality.* Vol. 43, pp. 358-370.

[125] I. Matiatos, A. Alexopoulos, and A. Godelitsas (2014). "Multivariate statistical analysis of the hydrogeochemical and isotopic composition of the groundwater resources in northeastern Peloponnesus (Greece),". *Science of The Total Environment.* Vol. 476, pp. 577-590.

[126] Y.-B. Wang, C.-W. Liu, P.-Y. Liao, and J.-J. Lee (2014). "Spatial pattern assessment of river water quality: implications of reducing the number of monitoring stations and chemical parameters,". *Environmental monitoring and assessment.* Vol. 186, pp. 1781-1792.

[127] K. P. Singh, A. Basant, A. Malik, and G. Jain (2009). "Artificial neural network modeling of the river water quality—a case study,". *Ecological Modelling.* Vol. 220, pp. 888-895.

[128] A. Najah, A. Elshafie, O. A. Karim, and O. Jaffar (2009). "Prediction of Johor River water quality parameters using artificial neural networks,". *European Journal of Scientific Research.* Vol. 28, pp. 422-435.

[129] E. A. Gatica, C. A. Almeida, M. A. Mallea, M. C. del Corigliano, and P. González (2012). "Water quality assessment, by statistical analysis, on rural and urban areas of Chocancharava River (Río Cuarto), Córdoba, Argentina,". *Environmental monitoring and assessment.* Vol. 184, pp. 7257-7274.

[130] C. A. Alfaro, B. Aydın, C. E. Valencia, E. Bullitt, and A. Ladha (2014). "Dimension reduction in principal component analysis for trees," *Computational Statistics & Data Analysis*. Vol. 74, pp. 157-179.

[131] T. Bouwmans and E. H. Zahzah (2014). "Robust PCA via Principal Component Pursuit: A review for a comparative evaluation in video surveillance,". *Computer Vision and Image Understanding.* Vol. 122, pp. 22-34.

[132] M. Kuznetsov and V. Strijov (2014). "Methods of expert estimations concordance for integral quality estimation,". *Expert Systems with Applications.* Vol. 41, pp. 1988-1996.

[133] Z. Liu, S. Wang, and L. Chen (2014). "Kernel Principal Component Analysis-Based Method for Fault Diagnosis of SINS," in *Knowledge Engineering and Management*, ed: Springer, 2014, pp. 633-639.

[134] E. Vincent, S. Araki, and P. Bofill (2009). "The 2008 signal separation evaluation campaign: A community-based approach to large-scale evaluation," in *Independent Component Analysis and Signal Separation*, ed: Springer, 2009, pp. 734-741.

[135] A. Hyvärinen and E. Oja (2000). "Independent component analysis: algorithms and applications,". *Neural networks.* Vol. 13, pp. 411-430.

[136] T. Taniguchi, K. Nakamura, S. Yamada, and M. Iwahara (2002). "An image synthesis method for eddy current testing based on extraction of defect orientation,". in *2002 IEEE International Magnetics Conference. INTERMAG Europe 2002. Digest of Technical Papers.*, 2002, p. GC3.

[137] S. R. H. Hoole (1993). "Artificial neural networks in the solution of inverse electromagnetic field problems,". *IEEE Transactions on Magnetics.* Vol. 29, pp. 1931-1934.

[138] M. Enokizono, T. Todaka, M. Akita, and S. Nagata (1993). "Rotational magnetic flux sensor with neural network for non-destructive testing,". *IEEE Transactions on Magnetics, Institute of Electrical and Electronics Engineers, United States.* Vol. 29(6), pp. 3195-3197

[139] F. C. Morabito and M. Campolo, "Location of plural defects in conductive plates via neural networks," *Magnetics, IEEE Transactions on,* vol. 31, pp. 1765-1768, 1995.

[140] T. Chady, M. Enokizono, R. Sikora, T. Todaka, and Y. Tsuchida (2001). "Natural crack recognition using inverse neural model and multi-frequency eddy current method,". *IEEE transactions on Magnetics.* Vol. 37, pp. 2797-2799.

[141] E. Mokotoff (2011). "Multicriteria Flow Shop Scheduling Problem,". *Enterprise Information Systems Design, Implementation and Management: Organizational Applications. Hershey, PA.* pp. 211-233.

[142] B. M. Wilamowski (2009). "Neural network architectures and learning algorithms,". *IEEE Industrial Electronics Magazine.* Vol. 3, pp. 56-63.

[143] F.-J. Chang and Y.-C. Chen (2001). "A counterpropagation fuzzy-neural network modeling approach to real time streamflow prediction,". *Journal of hydrology.* Vol. 245, pp. 153-164.

[144] L. Medsker and L. C. Jain (2010). "*Recurrent neural networks: design and applications,*". CRC press. Florida.

[145] O. Abdel-Hamid, A.-r. Mohamed, H. Jiang, and G. Penn (2012). "Applying convolutional neural networks concepts to hybrid NN-HMM model for speech recognition,". in *2012 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP).* pp. 4277-4280.

[146] M. Ibrahim, J. Claudel, D. Kourtiche, and M. Nadi (2013). "Geometric parameters optimization of planar interdigitated electrodes for bioimpedance spectroscopy,". *Journal of Electrical Bioimpedance.* Vol. 4, pp. 13-22.

[147] M. M. Yunus, S. Mukhopadhyay, M. Rahman, N. Zahidin, and S. Ibrahim (2013). "The Selection of Novel Planar Electromagnetic Sensors for the Application of Nitrate Contamination Detection," in *Smart Sensors for Real-Time Water Quality Monitoring*, ed: Springer, 2013, pp. 171-195.

[148] M. M. Yunus and S. Mukhopadhyay (2011). "Planar electromagnetic sensor for the detection of nitrate and contamination in natural water sources using electrochemical impedance spectroscopy approach," in *New Developments and Applications in Sensing Technology*, ed: Springer, 2011, pp. 39-63.

[149] S. Gupta (2009). "Sheep skin property estimation using a low-cost planar sensor,". in *2009 IEEE Instrumentation and Measurement Technology Conference*. 16 July 2009. Utworzono. pp. 482-486.

[150] A. Manut, A. Zoolfakar, N. Muhammad, and M. Zolkapli (2011). "Characterization of Inter Digital capacitor for water level sensor," in *2011 IEEE Regional Symposium on Micro and Nanoelectronics (RSM)*. pp. 359-363.

[151] G. Felic, D. Ng, and E. Skafidas (2013). "Investigation of Frequency Dependent Effects in Inductive Coils for Implantable Electronics," *IEEE Transection on Magnetic*. Vol. 49, pp. 1353-1360..

[152] K. Sundara-Rajan, A. V. Mamishev, and M. Zahn (2005). "Fringing electric and magnetic field sensors,". *Encyclopedia of Sensors.* Vol. 10, pp. 1-12.

[153] S. Palani, S.-Y. Liong, and P. Tkalich (2008). "An ANN application for water quality forecasting,". *Marine Pollution Bulletin.* Vol. 56, pp. 1586-1597.

[154] M. J. Diamantopoulou, D. M. Papamichail, and V. Z. Antonopoulos (2005). "The use of a Neural Network technique for the prediction of water quality parameters,". *Operational Research.* Vol. 5, pp. 115-125.

[155] M. Khashei and M. Bijari (2010). "An artificial neural network (p, d, q) model for timeseries forecasting,". *Expert Systems with Applications.* Vol. 37, pp. 479-489.

[156] G. Cybenko (1989). "Approximation by superpositions of a sigmoidal function,". *Mathematics of control, signals and systems.* Vol. 2, pp. 303-314.

[157] D. E. Rumelhart, G. E. Hinton, and R. J. Williams (1988). *Learning representations by back-propagating errors*: MIT Press, Cambridge, MA, USA.

[158] E. Cadenas and W. Rivera (2009). "Short term wind speed forecasting in La Venta, Oaxaca, México, using artificial neural networks,". *Renewable Energ.,* Vol. 34, pp. 274-278.

[159] N. Saravanan and K. Ramachandran (2010). "Incipient gear box fault diagnosis using discrete wavelet transform (DWT) for feature extraction and classification using artificial neural network (ANN),". *Expert Systems with Applications.* Vol. 37, pp. 4168-4181.

[160] L. Guo, D. Rivero, J. A. Seoane, and A. Pazos (2009). "Classification of EEG signals using relative wavelet energy and artificial neural networks,". in *Proceedings of the first ACM/SIGEVO Summit on Genetic and Evolutionary Computation*. pp. 177-184.

[161] L. Wilcox and W. Resch (1963). *Salt balance and leaching requirement in irrigated lands* vol. 1281: US Dept. of Agriculture.