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**PREDICTION OF DISSOLVED OXYGEN IN
HARBOURS USING ARTIFICIAL NEURAL
NETWORKS: AN APPLICATION TO THE PORT OF
COLOMBO**

By

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THIS THESIS WAS SUBMITTED TO THE DEPARTMENT OF CIVIL ENGINEERING OF
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DECLARATION

I hereby declare that the work included in the thesis in part or whole has not been submitted in any form for any other academic qualification of any institution.

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ABSTRACT

Maintenance of high dissolved oxygen (DO) level in harbours is highly important as it could give rise to catastrophic effects if it is depleted affecting day- to- day port functions such as dredging activities and other maintenance work. The depletion of DO results not only in toxic gases such as methane and hydrogen sulfide but also in accumulation of wastes. Frequent monitoring of DO is therefore imperative, but makes practical difficulties due to ship movements and other activities. Hence, prediction of DO with an empirical model using Artificial Neural Networks (ANNs) was done with success with an application to the Port of Colombo (PoC). This model aims to lessen the frequency of monitoring DO and to foresee the responses of the system due to environmental changes. The performances of ANNs were compared with Multiple Linear Regression (MLR). Monthly values of 14 water quality parameters at several depths for the period of four years from 1997 to year 2000 were collected. The values of weather parameters of rainfall and wind velocity for the corresponding period were also collected. The neural network possessing 7 inputs and 45 hidden neurons, performed well giving rise to correlation coefficient (R) as 0.87 and 0.67 for calibration and verification respectively. The inputs are temperature, depth and five rainfall intensities (including values on four immediate previous days). A sensitivity analysis was carried out to assess the potentials of small changes in each input on the neural network output. MLR model with 7 input variables indicated R to be 0.45 for calibration after several transformations. The temperature was the most influential variable among the ANN inputs affecting the output. In conclusion, it could be inferred that the ANN model is capable of predicting DO in PoC considerably well compared with MLR.

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LIST OF SYMBOLS

| <u>Symbol</u> | <u>Name</u> |
|----------------|---|
| α | Momentum |
| η | Learning parameter |
| b_1 | Change in Y for a unit change in X_2 keeping X_1 constant |
| b_1^* | Effect of X_1^* on Y_1^* keeping X_2^* constant. |
| b_2 | Change in Y for a unit change in X_2 keeping X_1 constant |
| b_2^* | Effect of X_2^* on Y_2^* keeping X_1^* constant |
| N | Number of pairs. |
| R | Correlation coefficient |
| R^2 | Determination coefficient |
| R_{YX_1} | Correlation of X_1 with Y |
| R_{YX_2} | Correlation of X_2 with Y |
| $R_{X_1X_2}$ | Correlation of X_1 with X_2 |
| $R_{X_2Y.X_1}$ | Partial correlation of X_2 and Y with X_1 Controlled. |
| S_{LM} | The Slope between low summary point and the middle of the curve. |
| S_{MH} | The Slope between middle summary point and the high summary point |
| sd_{X_1} | Standard deviation of X_1 . |
| sd_{X_2} | Standard deviation of X_2 . |
| sd_Y | Standard deviation of Y data. |



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| | |
|--------------|--|
| sd_{X_1} | Standard deviation of X_1 data. |
| sd_Y | Standard deviation of Y^* data. |
| $sd_{X_1^*}$ | Standard deviation of X_1^* data. |
| X_1 | Dependent variable. |
| X_2 | Dependent variable. |
| X^* | Standardized version of X . |
| X_H | X coordinate of the high summary point |
| X_L | X coordinate of the low summary point |
| X_M | X coordinate of the middle summary point |
| \bar{X} | Sample mean |
| Y | Independent variable |
| Y^* | Standardized version of Y |
| \bar{Y} | Sample mean |
| Y_H | Y coordinate of the high summary point |
| Y_L | Y coordinate of the low summary point. |
| Y_M | Y axis value of middle summary point. |



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LIST OF ABBREVIATIONS

| <u>Abbreviation</u> | <u>Name</u> |
|---------------------|--|
| Ammonium-N | Ammonium Nitrogen |
| ANN | Artificial Neural Network |
| ANN-16 | ANN model with 16 inputs |
| ANN-9 | ANN model with 9 inputs |
| ANN-7 | ANN model with 7 inputs |
| BPN | Backpropagation Technique |
| BQ | Bandaranayake Quay |
| CH ₄ | Methane |
| COD | Chemical Oxygen Demand |
| DO | Dissolved Oxygen |
| H ₂ S | Hydrogen Sulphide |
| JCT | Jaya Container Terminal |
| M | Mean |
| MLR | Multiple Linear Regression |
| MLR-16 | MLR model with 16 inputs |
| MLR-9 | MLR model with 9 inputs |
| MLR-7 | MLR model with 7 inputs |
| Nitrate-N | Nitrate Nitrogen |
| Nitrite-N | Nitrite Nitrogen |
| Organic-N | Organic Nitrogen |
| ORP | Oxygen Reduction Potential |
| PoC | Port of Colombo |
| PVQ | Prince Vijaya Quay |
| QEY | Queen Elisabeth Quay |
| Rain-1 | Rainfall intensity on the 1 st day |
| Rain-2 | Rainfall intensity on the 2 nd immediate previous day |



| | |
|---------|--|
| Rain-1 | Rainfall intensity on the 3 rd immediate previous day |
| Rain-1 | Rainfall intensity on the 4 th immediate previous day |
| Rain-1 | Rainfall intensity on the 5 th immediate previous day |
| RMS | Root Mean Square |
| SLPA | Sri Lanka Ports Authority |
| SD | Standard Deviation |
| SS | Suspended Solids |
| Total-N | Total Nitrogen |
| Total-P | Total Phosphorous |
| WinNN | Windows Neural network |



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