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From Sources to Solution

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Chapter 1
Enterococci Concentrations in Tropical Coastal Beaches in Malaysia Correlate Better With Pathogen Levels and Other Water Quality Indicators than Faecal Coliforms

Asmat Ahmad, Ayokunle Christopher Dada, Gires Usup and Heng Lee Yook

Abstract There is currently no bacteriological beach quality monitoring (BQM) program in place in Malaysia. To initiate cost-effective, sustainable bacteriological BQM schemes for the ultimate goal of protecting public health, policy decision makers need to be provided robust, indigenous empirical findings that validate appropriate water quality parameters for inclusion in such monitoring programs. This is the first study that assesses the validity of *enterococci* as an ideal indicator for bacteriological BQM in Malaysia using a multivariate approach. Beach water and sand samples from seven beach locations were analyzed for a total of twenty-one microbial and non-microbial water quality parameters. A multivariate approach incorporating cluster analyses (CA), principal component analyses (PCA), and factor analysis (FA) was also adopted. Apart from the weak correlations of *Staphylococcus aureus* with concentrations of *Vibro* species ($r = 0.302$, $p = 0.037$) and total coliforms ($r = 0.392$, $p = 0.006$) in seawater, no correlation existed between *S.aureus* concentration and other parameters. Faecal coliforms failed to correlate with any of the tested parameters. *Enterococci* also correlated with more quality parameters than faecal coliforms or any other indicator. PCA/FA clearly delineated *enterococci* and faecal coliforms as parameters that weighed

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strongly for BQM while *Staphylococcus aureus*, faecal coliforms and *enterococci* weighed strongly for beach sand quality monitoring. On the whole, higher correlations of *enterococci* level with other parameters than was observed for faecal coliforms suggest that the former be considered a preferred parameter of choice for BQM in Malaysia.

Keywords *Enterococci* · Indicator · Recreational Beaches · Bacteriological quality monitoring · Multivariate Approach

Highlights

- *Enterococci* presented with stronger weightings for BQM in Factor Analysis.
- *Enterococci* also correlated with more quality parameters than any other indicator.
- *Enterococci* may be considered a preferred indicator choice for BQM in Malaysia.

Introduction

In Western nations, beach water and sand quality monitoring has attracted significant attention in recent years owing to improved legislation. The situation may be particularly worrisome in less economically developed countries where legislative standards do not exist as a result of frail institutions and tight budgets. In such cases, a prevailing absence of surveillance schemes may allow in beaches undetected pollution from stormwater, domestic sewage and industrial effluents. The situation is exacerbated as less developed nations are often at a loss on how to develop workable standards for the purpose of beach water quality monitoring. Usually, relevant authorities consider water quality statistics and take a decision on what proportion of failures they think can be accepted based on a consideration of political factors, economic factors and suggested minimum action levels (MAC) that are hinged on available empirical data. In cases where there are no indigenous studies that present empirical findings which suggest epidemiologically proven action levels or maximum admissible concentrations that made a case for the initiation of a beach water bacteriological quality monitoring (BQM) program, a worst case scenario of political inaction and negligence might ultimately become observable. With a more or less generalist approach, a surveillance program is currently in place for marine water quality that lays emphasis on levels of faecal coliform (*E. coli*), oil and grease, total suspended solids and selected heavy metals. Public recreational beaches are however, apparently left out of these surveillance schemes. Recent review articles have highlighted potential impacts of tourism

activities, shipping, refinery effluent, land reclamation and coastal zone property development on recreational water quality in Malaysia has previously been highlighted (Dada et al. 2012; Praveena et al. 2011). This study aimed at generating correlations between *Enterococci* and other water quality parameters used in water quality monitoring. Second objective was to explore the use of multivariate techniques in validating an *Enterococci*-based indicator organism paradigm for use in bacteriological BQM in Malaysia.

Materials and Methods

Beaches considered were Pantai Irama, Senuk, Sabah, Cahaya Bulan, Kuala Besar, Sri Tujuh and Tok Bali. Physico-chemical parameters were measured on site using a YSI 556 hand-held multi-probe. *Enterococci* were recovered from beach water and sand via membrane filtration method using Slanetz and Bartley agar. Counts of *Staphylococcus aureus,* total viable bacteria, total/faecal coliforms and *Salmonella* were enumerated using mannitol salt agar, NaCl supplemented nutrient agar, chromogenic coliform agar and Salmonella-Shigella agar respectively. Geometric mean-based correlation analyses were conducted to explore relationships between *Enterococci* and other microbial and non-microbial parameters measured in the study. Following confirmation of goodness-of-fit using Kolmogorov–Smirnov (K–S) statistics, data obtained were z-scale transformed prior to further analysis. Significant PCs were extracted from the PCA and varimax rotated to generate verifactors (VFs) in Factor Analysis (FA) (Abdul-Wahab et al. 2005).

Results and Discussion

From Pearson correlation analysis, it was observed that *Enterococci* concentrations significantly correlated to more parameters than any other microbial or non-microbial parameter analyzed in this stud. Both seawater and sand concentrations of *Enterococci* correlated in varying strengths to the concentration of *Salmonella typhi* in water ($r = 0.445$, $p = 0.002$ and $r = 0.739$, $p = 0.000$ respectively). The correlation between *Enterococci* concentration in sand and the concentration of pathogens in seawater as was observed in this study supports the position of other studies that suggested beach sand can be a source of faecal indicator bacteria and pathogens to adjacent waters (Oshiro and Fujioka 1995). The correlation of *Enterococci* in seawater however was inversely correlated to temperature ($r = -0.590$, $p = 0.000$), salinity ($r = -0.386$, $p = 0.009$) and dissolved oxygen ($r = -0.537$, $p = 0.000$). The negative correlation of water temperature to *Enterococci* antagonizes the concerns that indicator organisms may grow in the environments as argued by a previous study that observed positive correlations between the two parameters in temperate locations (Goodwin et al. 2012). This

study was conducted in a tropical setting with typically high day temperature reaching up to 35 °C. This might have significant implications on population dynamics of the microorganisms studied.

Enterococci concentration in beach sand correlated inversely but in stronger terms with dissolved oxygen levels in seawater. Apart from the weak correlation of *Staphylococcus aureus* concentration in seawater with *Vibro* species ($r = 0.302$, $p = 0.037$) and total coliforms ($r = 0.392$, $p = 0.006$) in seawater, no other correlations existed between *Staphylococcus* concentration and other parameters. Similarly, concentration of *Staphylococcus aureus* in beach sand correlated weakly with those of *Vibro* species ($r = 0.360$, $p = 0.012$) and total coliforms ($r = 0.595$, $p = 0.000$) in beach sand. This observation questions the adoptability of *S. aureus* for use as beach water quality indicator in the considered location. Notwithstanding, findings from this study are in concert with El-Shenawy (2005) that reported that *S. aureus* did not correlate with various other indicators. Notably, faecal coliform concentration in seawater did not correlate with any of the parameters tested apart for inverse correlations with *Vibro cholerae* ($r = -0.436$, $p = 0.02$) in seawater. This observation presents a shadow of doubt on the appropriateness of faecal coliform concentration for seawater quality monitoring in the studied location. Interestingly also, faecal coliform concentration in sand also did not correlate with any of the tested beach sand quality parameters. On a general note, the results of the correlation analysis apparently indicate that *Enterococci* concentrations seem to be a preferred choice indicator bearing in mind that it correlated more and better with other microbial parameters. This observation is in concert with a previous report (WHO 2003).

All 21 variables of normalized data sets for the four different spatial regions obtained from hierarchical cluster analysis (CL1-4) in this study were used for principal component analysis (PCA). PC1-PC6 were retained as they had eigenvalues higher than 1 and were responsible for 86.3 % of the variance or information contained in the original data set. Following verimax rotation of significant PCs, the first six VFs retained spanned 80.3 % of the variance as opposed to 86.3 % as explained by the same number of PCs. For beach sand delineated parameters; *Staphylococcus aureus* (SAS), faecal coliforms (FCS), *enterococci* (ES) and total plate count (TPCS) emerged with strong positive loadings significantly contributing to the variance following verimax rotation in factor analysis (Fig. 1.1). On the other hand, delineated parameters which weighed strongly for beach water were e*nterococci* (EW) and faecal coliforms (FCW) (Fig. 1.1). However, *enterococci* concentration in seawater (EW) weighed strongly in the first verifactor which was responsible for 28.9 % of the total variance unlike faecal coliforms (FCW) which weighed strongly only in the second verifactor responsible for a lesser amount of variance (15.8 %). Barrell et al. (2000) argued that although faecal coliforms were also independently associated with illness in some studies, the apparent superiority of *enterococci* as indicators of health risk in both drinking and bathing waters remains undisputed.

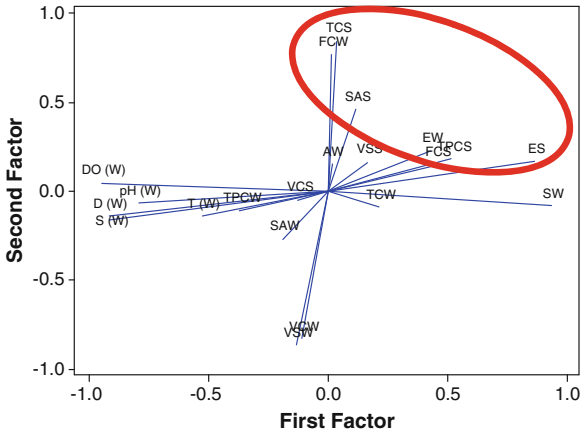

Fig. 1.1 Loading plots based on output from FA (1) *TPCS* total heterotrophic plate count of beach sediment samples (BSS) (2) *EW Enterococci* concentration in beach water samples (BWS) (3) *ES Enterococci* concentration in BSS (4) *SW Salmonella typhi* concentration in BWS (5) *SAW Staphylococcus aureus* concentration in BWS (6) *VCW Vibro cholerae* concentration in BWS (7) *VCS Vibrio cholerae* concentration in BSS (8) *VSW Vibrio* spp concentration in BWS (9) *VSS Vibrio* species concentration in BSS (10) *TCW* Total coliform count of BWS (11) *TCS* Total coliform count of BSS (12) *FCW* Faecal coliform count of BWS (13) *FCS* Faecal coliform count of BSS (14) *AW Aeromonas hydrophila* concentration in BWS (15) *EW Enterococci* concentration in BWS (16) *SAS Staphylococcus aureus* counts of BSS (17) *T* BWS temperature in °C (18) *D* Dissolved oxygen in % air saturation (19) *DO* Dissolved oxygen in mg/L (20) *pH* measure of the activity of the hydrogen ion concentration of BWS (21) *S* Salinity (in ppt) of BWS

Conclusion

Findings from this study provide meaningful evidence for policy direction particularly as it relates to the correlation of *Enterococci* with pathogens and other non-microbial parameters. *Enterococci* counts in beach water samples (EW) emerged with strong loadings and better correlations in our analysis, thus signifying its appropriateness for use as indicator in bacteriological BQM in Malaysia.

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Chapter 2
An Application of Artificial Neural Networks for the Prediction of Surface Ozone Concentrations in Malaysia

Negar Banan, Mohd Talib Latif, Liew Juneng and Md. Firoz Khan

Abstract In this study, an artificial neural network (ANN) was used to extract the complex relationships among divergent parameters that have the capabilities to predict O_3 concentrations which serve as an input to meteorological conditions and precursor concentrations. The ANN was trained using samples of daily maximum data provided by the Malaysian Department of the Environment (DOE) over a period of 9 year (2003–2011) in the towns of Gombak and Shah Alam in Malaysia. Furthermore, surface O_3 concentrations from the two locations (Gombak and Shah Alam) were estimated using surface meteorological variable as predictors for the ANN. Based on the results, it can be deduced that the relationship between the parameters and the O_3 concentrations are highly complex and non-linear. Analysis of the regression based model results between Gombak and Shah Alam were evaluated using the ANN. Based on the sample results it was confirmed that Shah Alam has the highest regression result of $R = 0.64$ in comparison with Gombak station. The inference drawn from this study shows that neural network model consistently gives superior predictions.

Keywords Artificial neural network · Surface ozone · Meteorological factors · Regression

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Highlights

- Artificial neural network model successfully predicts O_3 concentration.
- O_3 precursors and meteorological factors influenced predicted O_3 concentration.
- The proposed algorithm exhibits a high accuracy model.

Introduction

Ozone (O_3) is a major constituent of smog because it is readily released into the atmosphere as a result of photochemical oxidation and hence, a heavy air pollutant. Many studies have shown that the high presence of O_3 is capable of causing severe health respiratory disease (Huang et al. 2012; Neidell and Kinney 2010). Furthermore, it has been proved that there is a positive correlation between exposure to O_3 and decrease in lung function (Highfill and Coasta 1995). At high O_3 concentration, vegetation and forests are affected because of the phytotoxic nature of O_3. Higher concentration above 40 ppbv can be suggested to be harmful to the plants yield, biomass production, vitality and stress tolerance of forest trees (Fuhrer et al. 1997). It has been suggested that excessive level of O_3 may affect the ability of the forest to seize carbon in an event of excess of CO_2 in the future (Banan et al. 2013).

Modeling of O_3 concentrations is not a trivial procedure due to the intrinsic relationship between pollutants and meteorological variables (Sousa et al. 2007). However, different regression approaches have been adopted for forecasting surface O_3 with the predictor parameters varying from a few to a large sample inputs. Studies conducted by Wang et al. (2003) using statistical characteristics of O_3 to enable selection of appropriate predictors of daily maximum O_3 levels and highlighted the inclusion of parameters that affect both photochemical production and atmospheric accumulation of O_3 when forecasting O_3 levels. In this paper, ANN is used for the prediction of the daily maximum O_3 concentration in urban areas using the precursors and meteorological variables.

Materials and Methods

This experiment is carried out with two datasets collected from the air quality monitoring sites at the Department of the Environment (DOE) in Malaysia, which is managed by a private company, Alam Sekitar Sdn Bhd (ASMA). The daily maximum concentration of air pollutants such as; O_3, NO, NO_2, NO_x, CO, PM_{10} and NMHC and daily maximum meteorological variables (Ambient temperature (AT), Humidity (H), Wind speed (WS) and wind direction (WD)) were used. The logarithm of daily maximum O_3 concentrations of two stations, namely Gombak

Table 2.1 Characteristics of the datasets

Datasets	No. of attributes	Training set 70 %	Testing set 20 %	Validation set 10 %
Gombak	10	1019	291	146
Shah Alam	10	1732	495	247

and Shah Alam stations, that are located in Klang Valley in the middle of the Malaysian Peninsula, were derived and used for modeling. The concentration data were sourced from a 9-year period data samples (2003–2011). All the data were used to evaluate the predicting performance of the modeling data. The characteristics of the datasets used are summarized in Table 2.1.

ANN Model for Air Quality Prediction

The model of employed ANN is shown in Fig. 2.1. It comprises of three layers of neurons namely; input, hidden, output layers. The input layer is the first layer of neurons. Each input neural represents a separate attribute in the train/test datasets station (for example from NO to WD). The number of the inputs is equal to the number of attributes in the dataset. The number of nodes for other hidden layers is equal to the half of the number of nodes in the previous layer.

There has been recommendation that the input data be normalized between slightly offset values such as 0.1 and 0.9. One way to scale input and output variables in the interval [0.1, 0.9] as $P_n = 0.1 + (0.9–0.8)\ (P - P_{min})/(P_{max} - P_{min})$ (Xu et al. 2007).

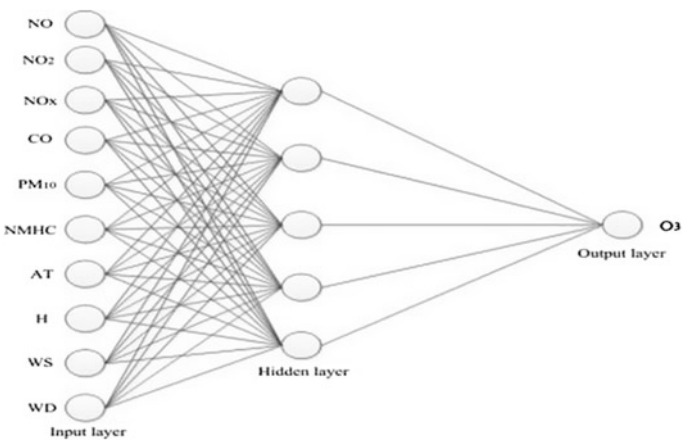

Fig. 2.1 Schematic of a neural network

Results and Discussion

In this study, artificial neural network was applied with input and targeted values normalized in the range of [0.1 and 0.9] before processing the data. The weights and biases were adjusted based on gradient-descent method in the training phase. The correlation coefficient (R) was chosen as the statistical criteria for measuring of the network performance. The result values were shown in Table 2.2.

Figure 2.2 depicts the network performance versus the number of epochs. At initialization of the network, the first values of the epochs were large due to training. Subsequently, the weights are adjusted to minimize this function which resulted in values decreasing. Meanwhile, a black dashed line is plotted which represents the best validation performance of the network. The training is stopped when the green line which represents the validation training set (network performance) cut-across with the black line.

In order to validate our hypothesis, regression analysis was performed to investigate the correlation between the actual and predicted results based on the value of correlation coefficient (R). There was a perfect fit value of R equal to 1 between the training data and the produced results. Figure 2.3 depicts the regression analysis plots of the network structure. From the regression graph, the perfect fit depicts that there is positive correlation between the predicted and targets as indicated by the solid line. The dashed line indicates the best fit produced by the algorithm.

Table 2.2 Correlation coefficient

Datasets	Correlation coefficient (R)
Gombak	0.62945
Shah Alam	0.63819

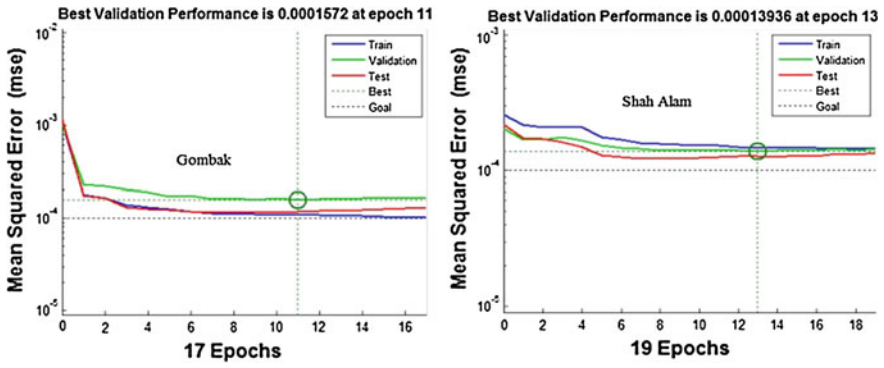

Fig. 2.2 Performance function of the network during training network structure, 10-5-1

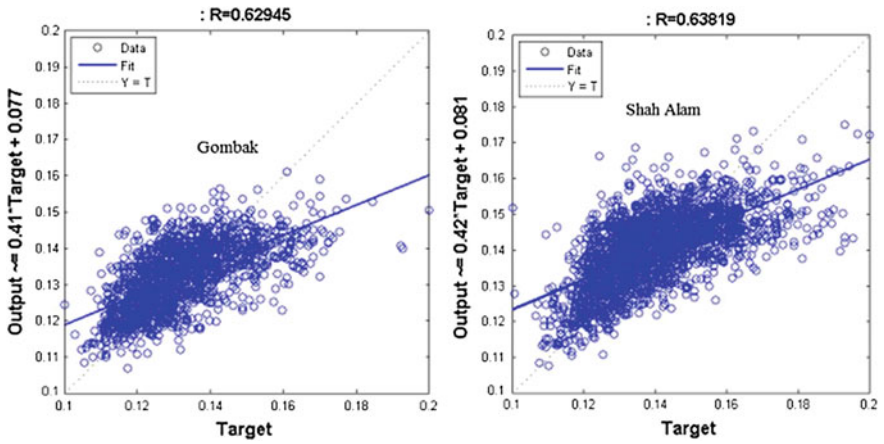

Fig. 2.3 Regression plot analysis network structure, 10-5-1

From Table 2.2, it can be seen that the model with network structure 10-5-1 is the optimal model for the air quality prediction as it yields the highest values of correlation coefficient (R). As depicted in Fig. 2.3, there is a match between predicted and measured values based on the value of correlation coefficient (R).

Conclusion

The input data to ANNs as used to forecast the O_3 concentrations is dependent on meteorological conditions and precursor concentrations. The network was trained using daily maximum data that were extracted from the Malaysian department of the Environment (DOE) during a 9-year period (2003–2011) in Malaysian towns of Gombak and Shah Alam. During the project under review, the surface O_3 concentrations were forecasted using surface meteorological variable as predictors for the artificial neural network on four experimental sites in Malaysia. The experimental results revealed that the proposed algorithm exhibits a high accuracy in predicting the O_3 concentrations. Additional study is hence needed to validate that the ANN algorithm can be used for the purpose of predicting O_3 concentrations with inputs from meteorological conditions and precursor concentrations during monsoon season.

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Chapter 3
Exposure to Indoor PM_{10} and Volatile Organic Compounds and Its Association with Respiratory Health Among Preschool Children from Urban and Rural Areas in Selangor

Nur Arasyi Yahaya and Juliana Jalaludin

Abstract Epidemiological studies have provided evidence that indoor exposure to particulate matter (PM_{10}) and Volatile Organic Compounds (VOCs) may decrease lung function among children. In this study, 96 respondents from both urban and rural areas were selected. Personal and socio-demographic background, and other related information were collected from standardized questionnaire adopted from the American Thoracic Society. Personal air sampling pumps and PbbRAE Portable VOC Monitor were used to measure indoor PM_{10} and VOCs in the respondents' houses. Lung function was measured using Chest Graph Spirometry. Results revealed that indoor PM_{10} level at home is higher in the urban area with mean (76.61 ± 17.53 μg/m3) compared to the rural area (48.37 ± 8.33 μg/m3) ($p < 0.001$). Indoor concentration of VOC indicate a significant difference ($p < 0.001$) between urban 0.083 ppm and rural area 0.035 ppm. Lung function; FVC % and FEV1 % were significantly higher in the rural area compared to the urban area ($p < 0.001$). The prevalence of an abnormal of FVC % was 75 % among the urban group and 37.5 % among the rural group. An abnormal FEV1 % was found in 75 % and 33.3 % of respondents in the urban and rural groups respectively. Respiratory symptoms which include cough ($p < 0.001$), phlegm ($p < 0.001$) and wheezing ($p < 0.001$) were significantly higher among children in the urban area compared to those in the rural area. There was significant association between PM_{10} concentration with cough ($p < 0.033$) and chest tightness ($p < 0.022$). However, there was no significant association between respiratory symptoms and VOCs concentration. PM_{10} does affect lung function and is associated with increased respiratory symptoms among studied population.

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