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MULTIPLE LINEAR REGRESSION (MLR) MODELING OF WASTEWATER IN URBAN REGION OF SOUTHERN MALAYSIA

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Abstract: A wastewater modeling contributes a valuable information in managing wastewater problems. Therefore, this study presented a multiple linear regression modeling on waste water in terms of heavy metal concentrations (lead, copper and zinc) and water quality parameters (BOD, COD, TSS, pH, temperature). The multiple linear regression was performed eight independent variables at three selected stations in six different times. The samples were collected from waste water produced by a variety of food stalls in the urban region of Southern Malaysia. The results showed that the water pH was not influenced by lead dependent variable at all sampling stations. Pearson correlation was performed to investigate the significant relationship among continuous variables such as BOD, COD, TSS, pH, temperature, lead, copper and zinc. The 'one sample t-test' was used in order to know the significant difference between numerical variables in all stations during the sampling period. Multiple comparisons and Fisher's LSD method were also implemented for investigating the differentiation of interested numerical variables.

KEYWORDS: ANOVA, multiple linear regression modeling, Pearson correlation, statistical analysis, water quality

Introduction

Application of the integrated study of chemistry and statistics for environmental modeling has been flourished significantly during recent decades. A lot of wastewater modeling for depicting environmental condition using diverse kinds of software has been offered in numerous previous investigations because it was informative, simple and fast. Among the environmental modeling of wastewater problems, the linear modeling was significantly applied for broad spectrum environmental application due to its valuable information, simplicity and rapidity. The MLR was selected for examining water quality and parameters and interaction between interested variables on water quality impact. Some interesting studies such as integral equations of Cartesian coordinate, Monte Carlo simulation of neural network, nonlinear modeling and factor analysis model were applied for determination of water quality (Abdullah and Asngari, 2011; Dagang *et al*., 2011; Lee *et al*., 2011; Rahman *et al*., 2011; Roudsari and Hosseini, 2011).

The waste water problem issues especially solid waste attracted great attention. Waste water treatment in developing Asian countries such as solid waste management, biological solid waste treatment, comprehensive waste management in academic campus was investigated in previous studies. Previous investigations reported about waste water treatment and solid waste management in developing Asian countries (Barbara *et al*., 2011; Razzaque *et al*., 2011; Sirajuddin *et al*., 2011; Sivakumaran and Baryalay, 2011). Investigations on waste management were expanded by the development of information system and performance optimization. Several modeling methods were performed in solid waste problems such as the algorithm model of multiple independent layers involving mechanical biological process, non linear elastic model directed on triaxial stress, computer model based on HELP (Hydrological Evaluation of Landfill Performance) for leachate estimation, and multiple mathematical modeling for uniform aeration in composting process (Agamuthu *et al*., 2011; Bari and Koenig, 2011; Hadrich *et al*., 2011; Le *et al*., 2011; Manandhar *et al*., 2011). Therefore, the aim of this study was to investigate the modeling system for wastewater produced by food stalls in the urban region of Southern Malaysia using multiple linear regression equation.

Several methods involving physical and chemical processes were conducted to reduce the pollution and undesired effects such as activated carbon, composite beads of chitosan/palm ash, bio elimination and bacterial detoxification, emulsion liquid membrane process, advanced oxidation process and chemical coagulation, reducing water hardness and turbidity, and kaolinite–illite clay mixture system (Fahmi *et al*., 2011; Eba *et al*., 2011; Ling *et al*., 2011; Masitah *et al*., 2011; Ogugbue and Sawidis, 2011; Othman *et al*., 2011; Ramalakshmi *et al*., 2012; Samadi *et al*., 2011).

This study extensively used two statistical models for the analysis of regression and Pearson correlation. The best model of multiple linear regression for wastewater modeling was provided with the modules of ANOVA and Pearson correlation that give us the information whether the model itself is statistically significant or not. The proposed linear model as well as the ANOVA and Pearson correlation will be used to illustrate the waste water profile based on the data from sampling.

Materials and Methods

Sampling

Five steps were performed in this study to investigate the modeling of waste water produced from food stalls in the urban region, i.e. (i) determination of sampling location, (ii) sampling and preservation, (iii) experimental analysis using appropriate instruments, (iv) data processing, and (v) modeling using selected software.

Samples were collected from waste water produced by selecting food stalls in relation to housing estate, school area, and office buildings in the urban region of Southern Malaysia. Samples were put in polyethylene bottles and preserved in a refrigerator at 4-10^{o}C. Samples for metal analysis were preserved with 69% concentrated nitric acid prior to instrumental measurements.

Water Analysis

Water quality parameters such as BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), TSS (Total Suspended Solid) and pH were determined in this study. The samples were collected in six different times (the 14th and 21nd December 1st year, 16st and 22nd February 2nd year and, 23rd and 28th March 2nd year).

BOD analysis was calculated by reduction of dissolved oxygen of samples. The BOD was defined in terms of mg/L. For the COD analysis, the water sample was initially acidified by sulfuric acid until pH < 2 and kept 4 – 10^{o}C for 7d preservation, potassium dichromate as oxidizing agent was added to the COD test followed by refluxing for 2h and titration using ferroin indicator until showing reddish brown color. The COD was defined as the different amount of mL potassium dichromate required for titrating the water sample and blank solution in terms of mg/L. TSS test was performed by placing the sample in refrigerator 4-10^{o}C for 7d without chemical preservation. The samples were filtered and the suspended left was dried in an oven at 105^{o}C. The weight of the dried suspended material is defined in mg/L. The pH was measured by calibration the pH meter for pH 4.0 and pH 10.0.

Three metals consist of copper (Cu), zinc (Zn) and lead (Pb) were selected as model metals in this study. The metal concentrations were determined by AAS (Atomic Absorption Spectroscopy). Table 1 presents the data of SPSS editor for water parameters (BOD, COD, TSS, pH), temperature and concentration of metals (Cu, Zn and Pb).

Data Analysis

The multiple linear regression model was obtained by data analysis using SPSS (statistical Package for Social Science) software version 19.0 (Chatterjee and Price, 1997; George and Maller, 2003). The sampling locations were defined as stations. Three stations were observed in this study. The water parameters, temperature and concentration of metals were defined as continuous numerical variables, while the times of observation and stations were described as categorical strings, which they have no intrinsic meaning.

Three linear equation models from waste water at three sampling stations were expected in this study. The concentration of Pb was designed as the dependent variable in the multiple linear regression model, while the other data was set up as predictors. The ANOVA table was used for the checking of model adequacy. The Pearson correlation test was applied for perceiving any significant interaction among interested: variables.

Data Processing

The code number used for the times of observation is described in Table 1. The 'Pb' data was described as the continuous numerical dependent variable entered in the dependent dialog box and other independent continues numerical variables were put in the independent(s) dialog box and followed the instruction of the entering multiple linear regression. The 'stepwise regression method' in the 'linear regression' menu was chosen to process the 'enter' mode.

Choosing independent and dependent variables in a multiple linear regression model was very useful in designing a multiple linear model by using waste water factors. The reason for choosing lead variable as dependent variable because the toxicity of lead is higher than the other selected two metals (copper and zinc). Less concentration of copper and zinc are required as conjugated enzymes in human body.

The general equation for the proposed multiple linear regression (MLR) modeling was formulated as follows,

$$Y = a + bX_1 + cX_2 + dX_3 + eX_4 + fX_5 + gX_6 + hX_7 \quad (1)$$

where: Y = lead dependent variable; X_1, X_2, X_3, X_4, X_5, X_6, X_7 = all independent variables including BOD, COD, TSS, pH, temperature, zinc and copper. The concentration of lead was

Table 1: SPSS editor for water data of selected stations in the urban region of Southern Malaysia. Station 1, 2 and 3: housing estates, schools and office buildings. Time 1, 2, 3, 4, 5 and 6 : 14 Dec, 21 Dec, 16 Feb, 22 Feb, 23 March and 28 March (note: BOD, COD, and TSS in mg/L; Cu, Zn and Pb in ppm; temp in °C).

Station	Time	BOD	COD	TSS	pH	Temp.	Cu	Zn	Pb
1	1	30.63	673	52	6.59	29.1	0.091	0.053	0.045
1	2	37.5	524	67	6.02	29.6	0.114	0.126	0.042
1	3	38.13	627	89	5.74	28.2	0.092	0.062	0.006
1	4	35	593	85	5.87	28.1	0.109	0.126	0.027
1	5	28.13	509	82	6.12	28.4	0.096	0.061	0.067
1	6	31.88	615	92	6.14	28.8	0.11	0.135	0.053
2	1	36.25	633	184	6.12	29.7	0.087	0.045	0.026
2	2	29.38	487	82	5.93	29.3	0.092	0.357	0.022
2	3	30.63	503	91	6.04	28.9	0.095	0.048	0.022
2	4	34.38	437	96	6.01	28.5	0.095	0.348	0.03
2	5	34.38	473	88	6.26	28.7	0.091	0.046	0.011
2	6	30.63	571	124	6.01	28.5	0.088	0.348	0.007
3	1	33.75	374	198	6.09	29.6	0.092	0.09	0.038
3	2	35.63	412	123	6.01	29.4	0.1	0.056	0.024
3	3	32.5	489	109	6.18	28.7	0.09	0.091	0.059
3	4	26.88	614	175	6.11	28.3	0.096	0.052	0.006
3	5	27.5	592	101	6.21	28.1	0.101	0.084	0.033
3	6	30	537	94	6.19	28.3	0.092	0.061	0.009

chosen as the dependent variable in the MLR modeling on account of toxic heavy metal. The interested independent variables included in the proposed MLR modeling were selected on account of water quality (BOD, COD and TSS), wastewater condition (pH and temperature) and common metals in foodwaste (zinc and copper). The order of independent variables could varied depending on the result of regression analysis (Chatterjee and Price, 1997; George and Maller, 2003).

The Univariate GLM (General Linear Model) with the Post Hoc test in LSD and Tukey modes was applied in this study to view the difference among continuous numerical variables. The sampling station was placed in the 'fixed factor' dialog box as a categorical string, and the continuous numerical variables were placed in the 'dependent variable' box.

Results and Discussion

The proposed multiple linear regression for wastewater model depicted the influence of all variables of interest (lead, copper, zinc, BOD, COD, TSS, pH and temperature) presented as the relationship between the dependent variable (lead) and the rest as independent variables. The lead was selected as the dependent variable because lead is known as a toxic heavy metal. Thus, the wastewater model indicated the degree of influence of independent variables with respect to lead. The selection of variables using for the model was based on facts that those variables were commonly involved in wastewater of the urban region under interest. Thus, the wastewater model is expected to be useful in moving the field study forward. The result from ANOVA table indicated the validity of the gained wastewater model. The Pearson

Table 2: The Pearson correlation of water data of Station 1 in the urban region of Southern Malaysia.

		Lead (ppm)	BOD (mg/L)	COD (mg/L)	TSS (mg/L)	pH	Temp. (ºC)	Copper (ppm)	Zinc (ppm)
Pearson Correllation	Lead (ppm)	1.000	-.826	-.450	-.201	.598	.354	.149	.042
	BOD (mg/L)	-.826	1.000	.117	.157	-.669	.059	.312	.332
	COD (mg/L)	-.450	.117	1.000	-.257	.347	-.020	-.382	-.202
	TSS (mg/L)	-.201	.157	-.257	1.000	-.748	-.670	.233	.345
	pH	.598	-.669	.347	-.748	1.000	.519	-.280	-.309
	Temp. (ºC)	.354	.059	-.020	-.670	.519	1.000	.333	.206
	Copper (ppm)	.149	.312	-.382	.233	-.280	.333	1.000	.969
	Zinc (ppm)	.042	.332	-.202	.345	-.309	.206	.969	1.000
Sig. (1-tailed)	Lead (ppm)	.	.021	.185	.351	.105	.245	.389	.468
	BOD (mg/L)	.021	.	.412	.383	.073	.455	.274	.260
	COD (mg/L)	.185	.412	.	.312	.250	.485	.227	.351
	TSS (mg/L)	.351	.383	.312	.	.044	.073	.329	.251
	pH	.105	.073	.250	.044	.	.146	.295	.276
	Temp. (ºC)	.245	.455	.485	.073	.146	.	.259	.347
	Copper (ppm)	.389	.274	.227	.329	.295	.259	.	.001
	Zinc (ppm)	.468	.260	.351	.251	.276	.347	.001	.

Note: encircled values in the table indicated strong correlation between two variables of interest, which followed the criteria of significant correlation of $t \leq 0.05$.

correlation indicated the degree of correlation between two variables of interest not a matter with the dependent or independent variable. Therefore, the proposed linear model provided with the ANOVA test and the Pearson correlation yielded valuable contribution in the management of wastewater problems. Table 1 showed the data of all variables of interest obtained from six successive samplings at three different urban region.

Sampling Station 1 in the Urban Region of Southern Malaysia

Table 2 shows the strong correlation between BOD and lead that was indicated by the significant value of 0.021 (< 0.05) and a negative interaction (-0.826). It was not surprising results since certain microorganisms (e.g. *E. coli*) like capturing lead. Solid waste of cooked food induced the bacterial growth and the lead contaminant in food was polluted from cooking utensils. Lead contaminant was suspected from many kinds of materials such as plastic and glass tubing using Plastic and glass tubing materials were suspected to be the source of lead contaminant (Eneh and Agunwamba, 2011). Since lead caused toxicity on human health, an investigation using a mixture of kaolinite-albite-montmorillonite-illite clay was conducted for lead treatment (Eba *et al*., 2011). Further observation on Pearson correlation (Table 2), proven that a positive correlation between zinc and copper (sig. value of 0.001) in the water was produced from food waste. It was suggested that zinc and copper were found in corroded material of water pipelines in the food stalls. Usually, zinc was used as a sacrificed anode in pipeline fabrication. Zinc was commonly used as a sacrificed anode in pipeline system to prevent corrosion. A strong positive correlation between pH and TSS (sig. value of 0.044) was also found in this investigation. More suspended materials in waste water were caused by increasing pH due to the formation of hydroxides. In addition, lead variable was the least varied factor among other continuous interested factors (BOD, COD, TSS, pH, temperature, copper, zinc) in Station 1, Therefore, this results indicated that lead contamination was produced from pipelines rather than that of food utensils.

Statistical results from Station 1 was shown in Table 3. Multiple linear regression for Station 1 was calculated in Table 4. Therefore, BOD, COD, TSS, temperature and zinc as predictors for lead variable was involved in the proposed multiple linear modeling. The general equation for the proposed multiple linear modeling was formulated as follows,

$$Y = a + bX_1 + cX_2 + dX_3 + eX_4 + fX \quad (1)$$

where: Y = variable lead; X_1 = variable BOD; X_2 = variable COD; X_3 = variable TSS; X_4 = variable temperature and X_5 = variable zinc.

By applying the data of unstandardized coefficients listed in Table 4, the MLR modeling for Station 1 was stated as follows,

$$Y = - 0.236 - 0.005X_1 + 0.016X_4 + 0.080X_5 \quad (2)$$

Thus, equation (2) is the accepted multiple linear model for illustrating the profile of waste water from Station 1 in the urban region under study. It was apparent that the BOD yielded negative impact on lead variable encountered with several microorganisms in the food stalls of interest. Using the unstandardized coefficients, the effects of COD and TSS on the concentration of lead were neglected. The proposed modeling revealed that the impacts of pH and copper on lead for this station were random, on the other word, there was no consistency between pH or copper toward lead.

Sampling Station 2 in the Urban Region of Southern Malaysia

Pearson correlation for Station 2 showed a strong negative correlation between TSS and COD (sig. value of 0.007) because more chemicals found as water soluble substances. It was also found that copper yielded significant negative influence on COD (sig. value of 0.016) assumed that possibility of copper reacts with other chemicals producing volatile matters. Moreover, zinc variable was caused by variation of corroded pipeline materials as sacrificed anode.

Table 3: The 'enter' model and ANOVA test with Pb dependent variable of Station 1 in the urban region of Southern Malaysia.

Model	Variables entered	Method		R	Rsquare
1	Zinc (ppm) COD (mg/L) Temperature (ºC) BOD (mg/L) TSS (mg/L)	Enter		1.000	1.000
		ANOVA			
Model		**Sum of square**	**df**	**Mean Square**	**Sig.**
1	Zinc (ppm) COD (mg/L) Temperature (ºC) BOD (mg/L) TSS (mg/L)	0.002 0.000 0.002	5 0 5	0.000	0.000

Note: the letter 'R' in the table denoted for the multiple correlation between the dependent variable Pb and the five variables in the regression model, i.e. zinc, COD, temp, BOD and TSS.

Table 4: The multiple linear regression of Station 1 in the urban region of Southern Malaysia.

Model		Unstandardized coefficients		Standardized coefficients	
		B	Std. error	Beta	Sig.
1	(constant)	-0.236	-0.236		0.00
	BOD (mg/L)	-0.005	-0.005	-0.888	0.00
	COD (mg/L)	0.000	0.000	-0.276	0.00
	TSS (mg/L)	0.000	0.000	0.118	0.00
	Temp (ºC)	0.016	0.016	0.450	0.00
	Zinc (ppm)	0.080	0.080	0.147	0.00

Excluded Variables

Model		t	Sig.	Collinearity Statistics Tolerance
1	pH	-	-	0.000
	Copper (ppm)	-	-	0.000

Note: The letter 'B' in the table denoted for the constant and coefficients for the regression model that measured the predicted values for lead. The 'Beta' denoted the standardized regression values based on z-scores of the respective 'B' values and used in the model of the present study.

The process of multiple linear modeling yielded the value of R square and the ANOVA test accepted the proposed linear modeling for Station 2 in the urban region of interest. Applying the general equation (1) for Y = lead, X_1 = BOD, X_2 = TSS, X_3 = temperature, X_4 = copper and X_5 = zinc, and taking the data of unstandardized coefficients for X_1, X_2, X_3, X_4 and X_5 as using the same SPSS procedure for Station 1, the proposed multiple linear modeling for Station 2 in the urban region under study becomes,

$$Y = -0.676 + 0.001X_1 + 0.012X_3 + 3.193X_4 + 0.025X_5 \quad (3)$$

Based on the result, the proposed modeling of Station 2 in the urban region of interest showed that the COD and pH variables had no linear impact on lead variable in this respective station. In addition, using the unstandardized coefficients for eq. (3), the effect of TSS on the concentration of lead was neglected.

Sampling Station 3 in the Urban Region of Southern Malaysia

A strong negative correlation between COD and BOD (sig. value of 0.002) was shown by Pearson correlation in Station 3. It was assumed that the microbial activities significantly influenced the chemical substances in food waste and then the chemicals in food will be oxidized by the presence of chemicals as catalyst. Another observation showed that temperature yielded significant positive effect on BOD (sig. value of 0.008). It was evident that the temperature of environment (28-29^{o}C) was suitable for bacterial growth. Warm temperature was caused by the condition of food stalls that are surrounded by office buildings. Previous report showed that the BOD reduction was affected by toxicity impact of organochlorine pesticide in surface water (Banaee and Ahmadi, 2011). A significant positive interaction was also found between zinc and lead, that both minerals were produced by the same source, i.e. the pipelines and cooking utensils. Using the 'one sample t-test', the investigation revealed that the concentration of lead showed no significant during December until March. This was suggested that lead pollution in waste water was produced by pipeline materials contamination. There was an interesting report that the heavy metal contamination was affected by the use of chicken manure and spilled chicken feed in rearing fish especially if fish was consumed for long periods of time. Heavy metal contamination was investigated in integrated chicken–fish farming especially on long time fish consuming (Nnaji *et al*., 2011).

The multiple linear modeling was also proposed to Station 3 by calculating the value of R square and ANOVA test. The random impact on lead concentration was shown by pH and temperature during sampling period. This was assumed that the varied pH and temperature gave no physical meaning from the perspective of chemistry. According to the general equation (1) for multiple linear modeling by taking the unstandardized coefficients as using the same SPSS procedure for station 1, which X_1 = BOD, X_2 = COD, X_3 = TSS, X_4 = copper and X_5 = zinc, while Y = lead, the proposed model for Station 3 in the urban region under study can be formulated as follows,

$$Y = -0.699 + 0.012 X_1 + 0.126X_4 + 1.255X_5 \quad (4)$$

Table 5: The Univariate GLM with Post Hoc test for copper dependent variable at all stations in the urban region of Southern Malaysia. (Note: bold-type values in the table denoted for significant difference of copper concentrations between the two stations of interest (t≤0.05)).

Dependent Variable: Copper (ppm)					
	Sampling station (A)	Sampling station (B)	Difference (A-B)	Std. Error	Sig.
Tukey HSD	Station 1	Station 2	.011	.004	**.037**
		Station 3	.007	.004	.215
	Station 2	Station 1	-.011	.004	.037
		Station 3	-.004	.004	.595
	Station 3	Station 1	-.007	.004	.215
		Station 2	.004	.004	.595
LSD	Station 1	Station 2	.011	.004	**.015**
		Station 3	.007	.004	.098
	Station 2	Station 1	-.011	.004	**.015**
		Station 3	-.004	.004	.338
	Station 3	Station 1	-.007	.004	.098
		Station 2	.004	.004	.338

The proposed model (eq.4) means that the interested predictors (BOD, COD, TSS, copper and zinc) yielded linear impact on the lead. Eq. (4) showed that the impact of COD and TSS on the concentration of lead were neglected.

All Stations of interest in the Urban Region of Southern Malaysia

The proposed model using the lead as dependent variable and other factors (BOD, COD, TSS, pH, temperature, copper and zinc) as predictors were not fit for all stations since the R square value was not suitable (≈0.500) and there was no statistical significance in the ANOVA test (the output not shown here). However, using the continuous numerical variables in the Univariate GLM, only the copper concentration showed significant difference between Station 1 and Station 2 in the urban region of interest as evidenced by Tukey (0.037) and LSD (0.015) in Table 5. The TSS dependent variable also showed significant difference between Station 1 and Station 3 in the urban region under study as evidenced by the values of LSD (0.014) and Tukey (0.035) (the output not shown here) . The LSD mode was generally more sensitive than the Tukey mode for some instances. The results was caused by many food stalls in Station 1 related to housing area, while limited food stalls found in Station 2 and Station 3 related to schools and office buildings in the urban region under study.

The statistical analysis in relation to the multiple linear modeling of waste water and the Pearson correlation is valuable for future research on water modeling and the study of interactions between heavy metals and water quality parameters. The application of Univariate GLM with the LSD mode in the Post Hoc test is also beneficial to know the effect of interested factor in the industrial effluents.

Conclusion

The combination of chemistry and statistics demonstrated a versatile tool particularly for waste water modeling which was investigated in this study to know the effect of interested factors such as heavy metals contaminant and water quality parameters. The correlation effects among the selected variables in waste water were performed by the Pearson correlation. The multiple linear modeling for the three respective stations in the urban region of interest stated that the pH factor gave no linear impact on the lead variable. The introduction of Univariate GLM with the LSD mode in the Post Hoc test exhibited that copper concentration was found to be different substantially between the crowded and less crowded food stalls in the region of interest.

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