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Research article

STATISTICAL APPROACH FOR WASTEWATER IN CAMPUS AREA LOCATED IN REGIONAL URBAN DISTRICT RELATED TO RESPECTIVE METALS (PB, CU AND ZN) AND WATER PARAMETERS (BOD, COD, TSS, PH AND TEMPERATURE)

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ABSTRACT: Wastewater problem is a never ending hot issue since fast growing industries in developing countries have serious impact on wastewater contamination. A wastewater model was performed using a linear approach corresponding with three elements (lead, copper and zinc) and water parameters (BOD, COD, TSS, pH and temperature) at three stations with respect to food stalls, boarding houses and laboratories area in academic campus. The samples were collected at six different times considering the busiest academic activities and student long break. The linear approach using ANOVA showed that water pH gave no impact on lead concentration at all stations. The Pearson correlation performed very strong relationship between copper and zinc concentrations at station with crowded food stalls. The Univariate General Linear Model with Post Hoc test in Tukey HSD and LSD modes showed significant difference of copper concentration between foodstalls area and boarding houses region.

Keywords: wastewater, ANOVA, Pearson correlation, Univariate model.

INTRODUCTION

Application of statistical methods in the field of environmental chemistry has been extended remarkably in the last decades. Wastewater problems have attracted a lot of attentions due to the ongoing rapid development of industrial activities and technology and therefore, environmental issues have blown up onto surface needed a deep thought in searching the way out. A lot of approaches from different angles have been developed to reduce environmental problems including waste problems. A lot of statistical techniques have been introduced in the environmental study in order to enhance the technique performance regarding its valuable information, simplicity and rapidity. With respect to wastewater problems, several investigations such as nonlinear modeling, factor analysis model, Monte Carlo simulation and Cartesian equation were reported in relation to water quality problems (Abdullah and Asngari, 2011; Lee *et al.*, 2011; Rahman *et al.*, 2011; Roudsari and Hosseini, 2011). Moreover, wastewater management in academic campus of developing Asian countries was intensively studied particularly in relation to optimization performance, algorithm model involving biological process, elastic model using triaxial stress, HELP computer model and uniform aeration modeling (Agamuthu *et al.*, 2011; Bari and Koenig, 2011; Hadrich *et al.*, 2011; Manandhar *et al.*, 2011; Rahman et al., 2011). Therefore, this study was focused on wastewater problems in campus area with respect to busiest academic activities and student long break at different locations applying simple statistical approaches. As a matter of fact, several environmental analysis were accomplished by some methods related to chemical and biological treatments in order to reduce undesired effects and pollutants applying activated carbon, beads of chitosan, kaolinite-illite clay mixture, liquid emulsion membrane, advanced oxidation process, chemical coagulation to reduce water hardness and turbidity, and bacterial detoxification (Agamuthu *et al.*, 2011; Bari and Koenig, 2011; Eba *et al.*, 2011; Hadrich *et al.*, 2011; Manandhar *et al.*, 2011; Ramalakshmi *et al.*, 2012; Samadi *et al.*, 2011).

On account of this reason, this study was interested in using simple statistical approach to perform the wastewater investigation in campus area applying a multiple linear regression model with ANOVA (Analysis of Variance) test, Pearson correlation and Univariate General Linear Model (GLM) with Post Hoc test.

Eight continuous variables consisted of three respective metals (lead, copper and zinc) and five water quality parameters (BOD, COD, TSS, pH and temperature) were used in this study. The three different sampling stations were established regarding crowded food stalls, boarding houses for students and academic staffs, and the place concentrated for laboratories and research centers. The six different sampling times were established from December to March regarding the busiest academic activities and student long break. The metals concentrations were determined by the Atomic Absorption Spectrophotometric (AAS) method and the water quality parameters were measured using a standard method for water quality. This study informed the predictors giving significant influence on the dependent variable at the respective station based on the result of linear approach using ANOVA, while the Pearson correlation informed the quality of relationship between variables of interest at respective station, and the Univariate GLM with Tukey and LSD modes showed the significant difference of selected dependent numerical variable between sampling stations of interest as categorical string.

MATERIALS AND METHOD

Sampling and Water Analysis

Wastewater samples were collected in polyethylene bottles from three different stations regarding the area of food stalls, boarding houses and laboratories in the campus region. Six successive sampling times were established regarding the busiest academic activities and student long break. Concentrated nitric acid of 69% was used to preserve samples prior to metal analysis. Samples in polyethylene bottles were preserved in a refrigerator at 4-10^{o}C.

The BOD analysis was determined based on the reduction of dissolved oxygen in wastewater samples. The COD analysis required sulfuric acid to obtain acid medium at $pH < 2$ and potassium bichromate to oxidize oxygen in wastewater followed by refluxing process and titration using ferroin indicator. The TSS analysis was done by keeping samples in refrigerator 4-10^{o}C followed by filtering process and drying the suspended left in an oven at 105^{o}C. The BOD, COD and TSS are defined in mg/L, respectively. A calibrated pH meter was used to measure the pH and the temperatures were *in situ* determined. An atomic absorption spectrophotometer was applied to determine the metals concentration with respect to lead, copper and zinc defined in mg/L. Table 1 presents the data of concentrations with respect to certain metals (lead, copper and zinc) and water quality parameters (BOD, COD, TSS, pH and temperature) at three different stations in six different sampling times.

Statistical Analysis

According to statistical terms, the concentrations of respective metals (lead, copper and zinc) and the water quality parameters (BOD, COD, TSS, pH and temperature) were described as the continuous numerical variables, while the sampling stations and sampling times described as the categorical strings. The multiple linear regression with ANOVA test established the concentration of lead as the dependent variable, while other numerical variables were considered as predictors or independent variables with respect to three different sampling stations in six successive sampling times as the categorical strings. The concentration of lead was chosen as the dependent variable on the reason of lead toxicity, while copper and zinc in small amounts are found in conyugated protein enzymes. Therefore, we may see the effects of water parameters (BOD, COD, TSS, pH and temperature) as well as copper and zinc upon the concentration of lead in the proposed multiple linear model.

The multiple linear model with the stepwise regression method in 'enter' mode produced three mathematical equations with respect to three different sampling stations. The general multiple linear model was proposed as eq (1) as follows:

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

Where: Y = lead dependent variable; X_1, X_2, X_3, X_4, X_5, X_6, X_7 are predictors involving BOD, COD, TSS, pH, temperature, zinc and copper.

Applying the 'enter' mode and ANOVA test, five predictors were accepted with respect to Station 1 (crowded food stalls) as shown in Table 2, i.e. zinc (mg/L), COD (mg/L), temperature (^{o}C), BOD (mg/L) and TSS (mg/L) after the 'enter' stepwise method rejected the pH and copper predictors from the linear model (Table 3). Moreover, based on 'B' values in 'unstandardized coefficients' as shown in Table 3, the predictors were reduced to BOD, temperature and zinc. The values of 'B' in 'unstandardized coefficients' were used as the constant and coefficients of the respective BOD, temperature and zinc predictors in the multiple linear model with respect to Station 1. Thus, the multiple linear model using the ANOVA test in 'enter' mode for Station 1 is as follows,

$$Y = -0.236 - 0.005X_1 + 0.016X_2 \text{ and } 0.080X_3 \qquad (2) \quad \text{for Station 1}$$

Where: Y = lead dependent variable; X_1, X_2 and X_3 are predictors denoted for BOD, temperature and zinc in eq (2) is the multiple linear model for Station 1.

By the same procedure, using the ‘enter’ mode and ANOVA test with respect to the values of ‘B’ in ‘unstandardized coefficients’, the multiple linear model for Station 2 (boarding houses) and Station 3 (laboratories), respectively, were obtained as follows:

$$Y = -0.676 + 0.001X_1 + 0.012X_2 + 3.193X_3 + 0.025X_4 \qquad (3) \quad \text{for Station 2}$$

Where: Y = lead dependent variable; X_1, X_2, X_3 and X_4 are predictors denoted for BOD, temperature, copper and zinc in eq (3) is the multiple linear model for Station 2.

$$Y = -0.699 + 0.012X_1 + 0.126X_2 + 1.255X_3 \qquad (4) \quad \text{for Station 3}$$

Where: Y = lead dependent variable; X_1, X_2 and X_3 are predictors denoted for BOD, copper and zinc in eq (4) is the multiple linear model for Station 3.

The multiple linear model is provided with the Pearson correlation module, which determines the degree of relationship between two numerical variables of interest not a matter with the dependent or independent variables. Table 4 presents the results of Pearson correlation module. As seen in Table 4 with respect to Pearson correlation row, it implies that higher value of Pearson correlation indicated stronger relationship between two numerical variables not a matter with linear or non linear relationship. The mutual relationship of Pearson correlation is confirmed by the value of sig.(1-tailed) that all values ≤ 0.05 indicates a strong relationship. The Univariate GLM with Post Hoc test in Tukey and LSD modes is another benefit in the statistical analysis in order to examine significant difference of selected numerical variable between two categorical strings. Table 5 showed the results of Univariate GLM of interest with respect to concentration of copper between two sampling stations. The concentration of copper is described as the selected continuous numerical variable, while sampling station as the categorical string. All statistical analysis were proceeded and executed applying SPSS (Statistical Package for Social Science) software following the guidance of Chatterjee and Price (1997) as well as George and Maller (2003).

RESULTS AND DISCUSSION

Regarding the concentration of metals (lead, copper and zinc) in Table 1, it is seen that all the values were lower than their critical values. International standard regulation for environmental quality (1979) established the critical values for lead, copper and zinc as follows: 0.1 mg/L, 0.2 mg/L and 2.0 mg/L, respectively. Moreover, the BOD values obtained by this study at all stations in all sampling times (Table 1) were lower than its critical value (50 mg/L) allowed by the International standard regulation (1979). The result of COD values (Table 1) were also found tolerable at all stations and sampling times since their values were lower than its critical value (100 mg/L).

Table 1. Water quality and heavy metal concentrations data at three sampling stations in six successive sampling times (note: BOD, COD and TSS in mg/L; Cu, Zn and Pb in mg/L; temp. in ^{o}C).

Station	Time	BOD	COD	TSS	pH	Temp	Cu	Zn	Pb
1	1	30.6	67.3	52	6.59	29.1	0.091	0.053	0.045
1	2	37.5	52.4	67	6.02	29.6	0.114	0.126	0.042
1	3	38.1	62.7	89	5.74	28.2	0.092	0.062	0.006
1	4	35	59.3	85	5.87	28.1	0.109	0.126	0.027
1	5	28.1	50.9	82	6.12	28.4	0.096	0.061	0.067
1	6	31.9	61.5	92	6.14	28.8	0.11	0.135	0.053
2	1	36.3	63.3	184	6.12	29.7	0.087	0.045	0.026
2	2	29.4	48.7	82	5.93	29.3	0.092	0.357	0.022
2	3	30.6	50.3	91	6.04	28.9	0.095	0.048	0.022
2	4	34.4	43.7	96	6.01	28.5	0.095	0.348	0.03
2	5	34.4	47.3	88	6.26	28.7	0.091	0.046	0.011
2	6	30.7	57.1	124	6.01	28.5	0.088	0.348	0.007
3	1	33.8	37.4	198	6.09	29.6	0.092	0.09	0.038
3	2	35.6	41.2	123	6.01	29.4	0.1	0.056	0.024
3	3	32.5	48.9	109	6.18	28.7	0.09	0.091	0.059
3	4	26.9	61.4	175	6.11	28.3	0.096	0.052	0.006
3	5	27.5	59.2	101	6.21	28.1	0.101	0.084	0.033
3	6	30	53.7	94	6.19	28.3	0.092	0.061	0.009

Generally, the TSS values at all stations and sampling times were still tolerable since the critical value of TSS is 100 mg/L. By highlighting on TSS values of station 3 (Table 1) during the sampling period except for the last sampling time were found slightly higher than its critical value, this phenomenon was related to the condition of Station 3 where research centers are concentrated in a certain place not a matter with busy academic activities or student long break since most post graduate students doing their research at all time of their study. However, the TSS values of station 2 at the first time (184 mg/L) and last time (124 mg/L) of sampling were found as high as that obtained by Station 3, it was suspected that the sampling was done closely to the area of research center and laboratories. It is to be noted that sampling activities were taken at different locations in the same sampling station. With respect to water pH and temperature (Table 1), all values obtained were tolerable. According to the International standard for environmental quality (1979), the acceptable values are 5.5 – 9 for pH and 40°C for temperature. The temperatures obtained (≈ 28 – 29°C) were found lower than that of tolerable value since the campus area located in rather high hilly region.

As it was mentioned above, lead was selected as the dependent variable for the multiple linear modeling due to its toxic effect. Plastic glass tubing applied in many food stalls and housing area as well as in labs was the subject to be the source of lead contaminant (Eneh and Agunwamba, 2011). On account of lead toxicity, a previous investigation reported a mixture of kaolinite clay using for lead treatment (Eba *et al.*, 2011). The proposed linear model implicated with selected variables since those variables were commonly found in campus wastewater of interest. By rewriting eq (2) for the multiple linear model of Station 1, it indicated that the concentration of lead was significantly influenced by the BOD, temperature and zinc.

$$Y = - 0.236 – 0.005X_1 + 0.016X_2 \text{ and } 0.080X_3 \qquad (2) \qquad \text{Station 1}$$

(Y = lead dependent variable; X_1, X_2 and X_3 are predictors denoted for BOD, temperature and zinc).

Station 1 was related to area with crowded food stalls and therefore, it was suspected that the foodstuffs possessed significant function with the role of microbial life affected on the concentration of lead. Regarding the effect of temperature on lead, It should be noted that the dissolution of lead salt might be influenced by the presence of other salts from the food waste in relation to common ion effect in water. It is not surprising since foodstuff with varied concentrations of zinc nutrient yielded significant effect on lead concentrations regarding their different properties in terms of solubility and salt formation.

By rewriting eq (2) as the obtained multiple linear model for Station 2, it showed that the concentration of lead was significantly affected by the BOD, temperature, copper and zinc.

$$Y = - 0.676 + 0.001X_1 + 0.012X_2 + 3.193X_3 + 0.025X_4 \qquad (3) \qquad \text{Station 2}$$

(Y = lead dependent variable; X_1, X_2, X_3 and X_4 are predictors denoted for BOD, temperature, copper and zinc).

The three predictors (BOD, temperature and zinc) in the linear model of Station 2 are similar with those predictors of Station 1 in giving the effect on lead concentration. It is noted that Station 2 is related to boarding houses for academic staffs and students. The domestic water in housing area may contain substantial microorganism due to food waste and therefore, the BOD affected lead concentration in wastewater. On the other hand, the temperature of domestic water (≈ 28-29°C) may form deposited lead salts in wastewater. It was assumed that the corroded pipelines in the housing area with sacrificed zinc anode gave significant impact on lead concentration in wastewater, while the damage copper wire buried in soil due to its lifetime was also assumed to give effect on lead concentration in campus wastewater of interest.

Regarding the multiple linear model for Station 3 as rewritten by eq (4), it showed that the concentration of lead in wastewater of laboratories and research center area was substantially affected by BOD, copper and zinc concentrations. It is unsurprising since those metals (lead, copper and zinc) had important role with the research activities of laboratories and research centers.

$$Y = - 0.699 + 0.012X_1 + 0.126X_2 + 1.255X_3 \qquad (4) \qquad \text{Station 3}$$

(Y = lead dependent variable; X_1, X_2 and X_3 are predictors denoted for BOD, copper and zinc).

It was assumed that the role of BOD in this matter was in relation to the substantial microbial activities in the surrounding soil properties. It could be deduced that the multiple linear model showed the role of BOD and zinc gave important effects on lead concentration in wastewater in the campus of interest not a matter with the conditions of area.

As a matter of fact, it should be noted that the campus area of interest was the subject for inducing bacterial growth due to waste water temperature (28-29^{o}C) as well as zinc passified anode in network infrastructure gave significant effects on lead concentration in wastewater. Indeed, the colored soil and reddish brown colloidal formation in soil water in the campus area of interest indicate the presence of substantial minerals in campus wastewater.

Table 2. The ANOVA test with 'enter' method for Station 1 with lead dependent variable.

Method	Predictor	ANOVA			
		Sum of square	df	Mean square	Sig.
'Enter'	Zinc (mg/L)	0.002	5	0.000	0.000
	COD (mg/L)	0.000	0		
	Temp (oC)	0.002	5		
	BOD (mg/L)				
	TSS (mg/L)				

Table 3. The values of 'B' in unstandardized coefficients were coefficients of corresponding variable in the multiple linear model for Station 1 (note: COD and TSS were not included in the model due to zero value of 'B').

method	predictor	Unstandardized coefficients		Excluded variable
		B	Std. error	
'Enter'	(constant)	- 0.236	- 0.236	pH copper (mg/L)
	BOD (mg/L)	- 0.005	- 0.005	
	COD (mg/L)	0.000	0.000	
	TSS (mg/L)	0.000	0.000	
	Temp (oC)	0.016	0.016	
	Zinc (mg/L)	0.080	0.080	

In order to examine the degree of relationship between numerical variables of interest not necessary with dependent variable or predictor, the Pearson correlation (Table 4) verified strong correlation between BOD and lead (sig. 1-tailed: 0.021) at Station 1, which is consistent with the result of the corresponding multiple linear model performed by eq. (2). Probably the relationship between BOD and lead can be viewed based on the report of previous investigation corresponding to BOD reduction influenced by the impact of organochlorine pesticide in surface water (Banaee and Ahmadi, 2011).

Table 4 The Pearson correlation for Station 1 (foodstalls area) involving all numerical variables of interest.

		lead (ppm)	BOD (mg/L)	COD (mg/L)	TSS (mg/L)	pH	temp (oC)	copper (ppm)	zinc (ppm)
Pearson Correlation	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	.

Highly frequent exposure by chemical pesticides for killing harmful insects in campus area of interest was assumed to cause the change of BOD and mineral values. Moreover, the Pearson correlation showed strong relationship between wastewater pH and TSS (sig. 1-tailed of 0.044) at Station 1. This statement is reasonable since Station 1 is corresponding with foodstalls area, and foodstalls acitivities implicated with the role of pH and TSS. Futhermore, the Pearson correlation also showed strong relationship between copper and zinc (sig. 1-tailed: 0.001) in relation to food stalls area; this is reasonable since copper and zinc are often found together in foodstuffs in relation to metallic conyugated proteins. A previous investigation reported heavy metals contamination had found in long time chicken-fish farming (Nnaji *et al*., 2011). In the context of examining any relationship between similar categorical strings with respect to selected numerical variable, the Univariate GLM with Post Hoc test performed significant difference of copper concentration between Station 1 and Station 2 according to Tukey mode (sig. 0.037) and LSD mode (sig. 0.015) as shown in Table 5. Station 1 is related to crowded foodstalls and Station 2 corresponding with boarding houses for academic staffs and students, thus, this verification is reasonable. It was suspected that corroded pipelines in boarding houses (Station 2) gave strong contribution of copper to wastewater in the corresponding station. Furthermore, the verification of significant difference of copper between sampling stations of interest was discussed in Friedman One-way ANOVA that is beyond the scope of this context. Several statistical trials on Univariate GLM with Post Hoc test showed that the concentration of copper posed significant difference between sampling stations of interest but not other numerical variables.

Table 5 The Univariate GLM with Post Hoc test for copper dependent variable (note: bold-type values in the table described significant difference of copper concentrations between two stations based on t≤0.05).

Dependent variable: copper (mg/L)					
	Sampling station (A)	Sampling station (B)	Difference (A-B)	Std. error	Sig.
Tukey	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

CONCLUSION

The proposed multiple linear model of wastewater applying ANOVA test for all stations of interest with respect to lead dependent variable is moderately consistent with the real condition of the corresponding campus area in terms of heavy metal contamination and water quality parameters related to soil condition, campus infrastructure and academic activities. Other results such as the Pearson correlation and Univariate GLM with Post Hoc test were also in agreement with the real condition regarding the metal concentration in wastewater and food stalls activities in the related campus area.

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