

Simulation of Metal Contents through Correlated Optimal Monitoring Metals of Dagu River Sediments

Jingmei Sun, Zhichao Wang, Reng Li, Degang Ma*
School of Environmental Science and Engineering,
Tianjin University
Tianjin 300072, P. R. China
E-mail: dgma@tju.edu.cn, jmsun@tju.edu.cn

Baoshan Liu
CNOOC Tianjin Chemical Research & Design Institute,
Tianjin 300131, P. R. China
E-mail: liubaoshan1983@163.com

Abstract—Determination of pollutants for river sediments is essential and valuable. To allow a reduction in the number of monitoring metals analyzed in the future monitoring of watercourse, statistic analysis of heavy metals in Dagu River sediments was conducted and a simulation model was developed. Results show that all investigated metals except Zn and Ni in Dagu River sediments are positively correlated with three or more than three other metals. The optimal monitoring metals of Dagu River sediments are Pb (or Cr), Ni, Hg and Zn based on the correlations and their correlation coefficients of metals. To determine metal contents in Dagu River sediments in the future, only detection of the optimal monitoring metals in each sampling transect are required. The pollutant levels of other metals (As, Cd, Cr/Pb and Cu) can be simulated through well correlated metals using the simulation model developed from a non-linear function of Sigmoid $f(x) = \frac{1}{1+e^{-x}}$, a BP manual neural network model.

Keywords- River sediment, Correlation, Optimal monitoring metals, Simulation, BP manual neural network model

I. INTRODUCTION

Dagu River is one of the two main sewage rivers of Tianjin and undertakes the discharging of wastewaters from south of Haihe. It begins from the Xianyang Road pump station of Nankai district and ends at Dongdagu pump station of Tanggu district, with a total length of 67.5 km. The river sediments have been gradually silting the watercourse. Heavy metals are non-biodegradable pollutants, thus will accumulate in sediments. Periodic monitoring and prediction of heavy metals in sediments to learn the pollution of riverbed are necessary. However, periodic monitoring of river sediments is not the regular work in most China cities.

Many factors affect the distribution and correlation of heavy metals in river sediments, including the numbers and positions of pollution sources (outfalls) along riversides, transect formation of watercourse, water flow rate and flux, runtime of upriver and downstream pump stations, etc. It is difficult to develop a mathematic model to simulate/predict the metal content and distribution of river sediments if there is no enough historical data of each sampling transect. However, previous investigation [1] shows that one metal may be well correlated with another metal or other metals in Dagu River sediments. BP manual neural network model,

which is suitable for non-linear simulation, can be used to simulate one metal or metals using another metal or other metals in the same transect sediment. The advantage of the model is that it is not required to determine which non-linear function it belongs to. Therefore, calculation of many parameters is avoided. This provides many conveniences to practical engineering.

The main objectives of this study are to determine the optimal monitoring metals of Dagu River sediments based on the correlation between metals in sediments, then to simulate other correlated metals by BP manual neural network model. Therefore, the numbers of metals analyzed in future monitoring can be reduced significantly.

II. METHODOLOGY

A. Sampling Positions and Methods

Based on the characteristics of watercourse, the physiognomy and the boundary of towns, 28 representative monitoring transects were selected for the systematic monitoring along the approximately 30 km suburb section of Dagu Sewage River, as shown in Fig. 1a. The sediment sample of each transect was obtained by mixing the equal amount of sediment samples from the five sampling positions of each transect (see Fig. 1b).

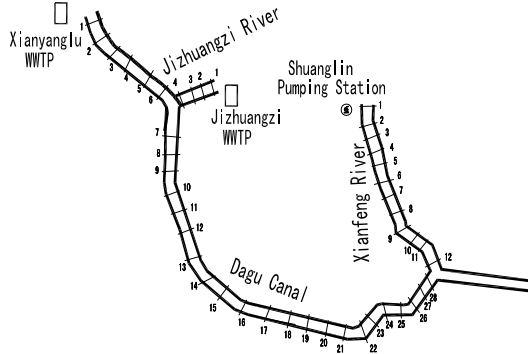
B. Simulation of Metal Content Using a BP Manual Neural Network Model

Trial calculations on network structure (including layers, neurons and training functions, etc.) and training parameters (such as training speed and step size, etc.) are firstly conducted using Matlab software in a conservative way, i.e. by balancing the training speed and the precision. A non-

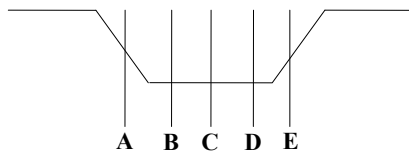
linear activation function of Sigmoid (i.e. $f(x) = \frac{1}{1+e^{-x}}$) is used between the input layer and the implicit layer. A linear activation function of Purelin is adopted between the implicit layer and the output layer. Model parameters used are: one implicit layer, 10 neurons in the implicit layer, 0.01 for training speed, 1000 for training cycle, Trainrp being used as training function, 0.01 for expected error, one input unit and one output unit.

Random 5 out of the total 28 monitoring transects of Dagu River are selected. Their detected metal contents are

used as the test data to develop the simulation model. Then, for well correlated two metals, the contents of one metal can be used to simulate the other metal content using the developed simulation model.



(a) Sampling transects along Dagu River



(b) Sampling positions in each transect

Figure 1. Sketch map of sampling positions

III. RESULTS AND DISCUSSION

A. Determination of the optimal monitoring metals based on correlation of Metals in Dagu River Sediments

Samples in the selected 28 representative monitoring transects (see Fig. 1) were withdrawn according to the method introduced in section 2.1. Heavy metal contents in each transect were detected [2]. The correlation coefficient matrix of investigated metals was conducted using statistic analysis software (SAS for Windows) [1]. Table 1, rearranged from the correlation coefficient matrix, shows the correlated metals and their correlation coefficients of each investigated heavy metal in Dagu River sediments.

Table 1 indicates that in the whole-line investigation, only zinc (Zn) has poor correlation (the correlation coefficient of less than 0.5) with all other investigated metals and Ni is well correlated with only one metal (i.e. Cd, with the correlation coefficient of 0.66). All other investigated metals have good positive correlation (the correlation coefficient of more than 0.5) with three or more than three other metals. This indicates a similar distribution characteristic of some investigated metals in Dagu River sediments and some relatively stable exterior pollution to Dagu River.

Metal Element	correlation coefficients of correlated metals							Total Numbers of Correlated Metal
	As	Hg	Pb	Cd	Cr	Cu	Ni	
As			0.68	0.60	0.70			3
Hg			0.53	0.57		0.53		3
Pb	0.68	0.53		0.53	0.86	0.83		5
Cd	0.60	0.57	0.53		0.62		0.66	5
Cr	0.70		0.86	0.62		0.66		4
Cu	0.53		0.83		0.66			3
Ni				0.66				1
Zn								0

Table 1 also shows that in the whole-line investigation, Pb content is well correlated with As, Cr or Cu content with the correlation coefficients of 0.68, 0.86 or 0.83, respectively. Cr content is well correlated with As, Pb, Cd or Cu content with the correlation coefficients of 0.70, 0.86, 0.62 or 0.66, respectively. Pb and Cr have the most well correlated metals (the correlation coefficient of more than 0.6). On the other hand, Zn and Hg are not well correlated with any other investigated metals (all correlation coefficients are lower than 0.6).

Therefore, to know all metal contents in the whole line of Dagu River sediments, one choice is that only contents of Pb, Ni, Hg and Zn are detected. Contents of As, Cr and Cu can be simulated by the detected Pb content and content of Cd can be simulated by the detected Ni content through their correlations. Another choice is that only contents of Cr, Hg and Zn are detected. Contents of As, Cd, Cr and Cu can be further simulated by the detected Cr content and content of Ni can be further simulated by the simulated Cd content through their correlations.

The optimal monitoring metals of Dagu River sediments would be Pb (or Cr), Ni, Hg and Zn.

B. Simulation of correlated metals using BP manual neural network model

Random 5 (e.g., transects 1#, 7#, 13#, 20# and 26#) out of the total 28 monitoring transects of Dagu River sediments are selected. Their detected metal contents are used as the test data to develop the simulation model. Fig. 2 shows the simulation results of As, Cr and Cu content by the detected Pb content and the simulation results of Cd content by the detected Ni content using the BP manual neural network model developed from a non-linear function of Sigmoid

$f(x) = \frac{1}{1+e^{-x}}$ following the procedures described in Methodology. For a comparison, the corresponding detected data (solid circular points) and relative simulation errors (solid columns) are also shown in Fig. 2.

TABLE I. CORRELATED METALS AND THEIR CORRELATION COEFFICIENTS IN DAGU RIVER SEDIMENTS

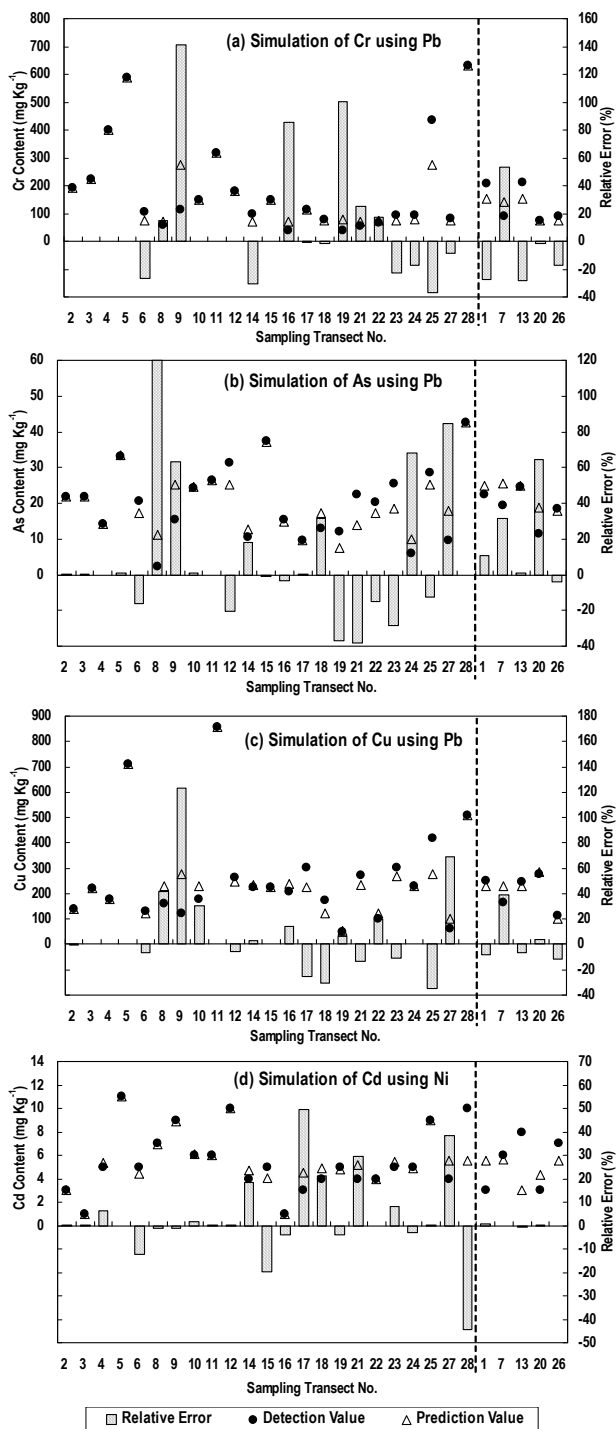


Figure 2. Simulation results using the BP manual neural network model.

Fig. 2 shows that the simulated metal contents of Dagu River sediments (open triangular points) are well close to the corresponding detected metals (solid circular points). The relative simulation errors (solid columns of Fig. 2) of most monitoring transects fall between $\pm 50\%$. This indicates that the method using the optimal metal contents of sampling

transects to simulate other correlated metal content(s) is acceptable in practice on the basis of reasonable periodical whole-line monitoring. On the other hand, the relative simulation error of some transects are very high. For example, in the simulation of As content using detected Pb content, the relative simulation error at monitoring transect 8# is as high as 365%. Such high relative error may be because only five monitoring data of one whole-line investigation are used to develop the BP manual neural network model. It is believed that in the future, if more monitoring data are collected and used to model development, simulation precision would be further improved.

IV. CONCLUSION

Statistic analysis of heavy metals in Dagu River sediments suggests that the optimal monitoring metals of Dagu River sediments are Pb (or Cr), Ni, Hg and Zn based on the correlations and their correlation coefficients of metals. Other metals (As, Cd, Cr/Pb and Cu) can be simulated through well correlated metals using a simulation model developed from a non-linear function of Sigmoid

$f(x) = \frac{1}{1+e^{-x}}$, a BP manual neural network model. The relative simulation errors of most sampling transect using the current monitoring data fall between $\pm 50\%$. It is acceptable in practical engineering.

ACKNOWLEDGMENT

This study was supported in part by a research funding from National Basic Research Program of China (Contract No. 2007CB407306) and in part by a National Nature Science Foundation of China (Contract No. 50708063).

REFERENCES

- [1] J. M. Sun, R. Li, J. J. Huang, Y. Zheng, and J. S. Cao. "Determination of Optimal Sampling Transects for Heavy Metal Contaminated Dagu River Sediments," International Conference on Bioinformatics and Biomedical Engineering (iCBBE2010), June 21-23, 2010 Chengdu, China.
- [2] R. Li. Study on Characteristics, Distribution, Dredging and Disposal of Sediment from Sewage River. Ph.D. Dissertation, Tianjin University, 2005.