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Influent Flow Rate Effect On Sewage Pump Station Performance Based On Organic And Sediment Loading

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ABSTRACT

The performance of sewage pumps stations affected by many factors through its work time which produce undesired transportation efficiency. This paper is focus on the use of artificial neural network and multiple linear regression (MLR) models for prediction the major sewage pump station in Baghdad city. The data used in this work were obtained from Al-Habibia sewage pump station during specified records- three years in Rusafa district, Baghdad. Pumping capability of the stations was recognized by considering the influent input importance of discharge, total suspended solids (TSS) and biological oxygen demand (BOD). In addition, the chemical oxygen demands (COD), pH and chloride (Cl). The proposed model performance has compared with the correlation coefficient (r). The suitable structure design of neural network model is examined through many trials, error, preparations and evaluation steps. Two prediction models of organic and sediment loading are presented. Results found that the estimating of the organic and sediment loading by ANN model could be successful. Moreover, results showed that influent discharge rate have more effect on organic and sediment loading predicting to other parameters.

Key words: sewage pump station, flow rates, organic load, sediment load, modelling.

تأثير معدل الجريان المتدفق على اداء محطة ضخ مياه الصرف الصحي على أساس الأداء العضوي ومعدل الرواسب

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طالبة دراسات عليا/ماجستير

الخلاصة

أداء محطات مضخات الصرف الصحي المتأثرة بالعديد من العوامل من خلال وقت عملها والتي تنتج كفاءة نقل غير مرغوب فيها. تركز هذه الورقة على استخدام الشبكة العصبية الاصطناعية ونماذج الانحدار الخطي المتعدد (MLR) للتنبؤ بمحطة ضخ المجاري الرئيسية في مدينة بغداد. تم الحصول على البيانات المستخدمة في هذا العمل من محطة الحبيبية لضخ الصرف الصحي خلال السجلات المحددة - ثلاث سنوات في منطقة الكرخ، بغداد. تم التعرف على قدرة الضخ للمحطات من خلال النظر في أهمية المدخلات المؤثرة للتصريف، والمواد الصلبة العالقة الكلية (TSS) والطلب البيولوجي على الأوكسجين (BOD) بالإضافة إلى ذلك، الأوكسجين الكيماوي المستهلك (COD)، الاس الهيدروجيني والكلوريد (Cl). تمت مقارنة أداء النموذج المقترح مع معامل الارتباط (r). يتم فحص تصميم الهيكل المناسب لنموذج الشبكة العصبية من خلال العديد من التجارب والخطأ والاستعدادات وخطوات التقييم. تم تقديم نموذجين للتنبؤ بالتحميل العضوي وتحميل الرواسب. وجدت النتيجة أن تقدير التحميل العضوي وتحميل الرواسب بواسطة نموذج ANN قد يكون ناجحاً. علاوة على ذلك، أظهرت النتائج أن معدل التصريف المؤثر يكون له تأثير أكبر على التحميل العضوي وتحميل الرواسب مع توقع معايير أخرى.

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الكلمات الرئيسية: محطة ضخ مياه الصرف الصحي، التصارييف، التحميل العضوي، معدل الرواسب، النمذجة.

1. INTRODUCTION

Sewage pump stations (SPS) are transitional structure that combined native and storm sewage from many conveniences to sewage treatment places or other plants for discarding considerations. Operation of a sewage pump station is often affected by a variety of physical, chemical, and biological factors of raw wastewater. In order to follow the station performance during the operation, measurements would not be sufficient. The internal parts in this stations might require to replace and mended to guarantee the hydraulic performance requirements which prevent any failure phenomena, **Hemed, 2015**. Many researchers have been projected in the pump station modeling as in, **Slys' and Dziopak, 2011**. They had been talked about problems associated with the mathematic formulations and developed the software based design and simulation of preservation tank collaborating with sewage pump station in the Przemysl left side river parts. The optimization of mathematical formula to running the cost in the sewage pumping station has been proposed by **Chaball and Stanko, 2014**, which suggested model contains a simulation of multi frequency change in sewage pump speed to provide high running cost.

The simulation model based evaluation of sewage flow in treat water allocation has designed by **Aleisa, et al., 2015**. They illustrate that the potential of 2050 waste water network will capable to carry out the capacity of sewage flow able be expecting for Al-sulaibiy plant will attain to improved capacity of initial followed by Umm Al-Hayman wastewater treatment plant (WWTP) plants. The prediction of wastewater treatment plant behavioral with coefficient of correlation between experiential and expected output level by ANN has proposed in **Abdullah, et al., 2015**. Prediction of the major water quality parameters in Gaza WWTP by using ANN and MLR has introduced by **Mazen, et al., 2018**, while Sewer condition changes are predicted and develop a deterioration models (the multiple discriminant model (MDM) and neural network model (NNM)), **Alsaqqar, et al., 2017**. They showed that a better control of SPS could provide by mathematical tool improvements to expect the performance of station depend on earlier period parameters testing. The objective of this research to study the influent flow rate effect on Al-Habibia sewage pump station performance based on organic and sediment loading using two mathematical model artificial neural network (ANN) and multiple linear regression (MLR) of predict the sewage pump station conditions changes has been developed.

2. MATERIAL AND METHODS

2.1 Study Area Description

Al-Habibia sewage pump station where selected in this study which is one of the large main sewage pump station in the side of Al-Rusafa in Baghdad city (N33.36700°, E44.47213°) which located on Zublin trunk sewer to collects the wastewater from the regions, AL-Shaab, AL-Sader1, Al-Sader2 as shown in **Fig. 1**, and lift and transfer sewage to Al-Rustamyia WWTP.



Figure 1. Zublin trunk sewer and Al-Habibia pump station plants.

The total design capacity of Al-Habibia SPS is $11.5 \text{ m}^3/\text{sec}$, so it is qualified for handling the inflow sewage discharge. A 3 m sewer enters the SPS into two stages, each stage has two sewers of 2 m diameter with a manually cleaned bar screen to remove big and floated solids. Then, sewage flows into two wet wells each of $(3.5 \times 5 \times 7) \text{ m}$ in volume. After that, two dry pits adjacent to the wet wells, each pit consists of five pumps. Sewage is collected in a collection chamber of volume $(4 \times 48 \times 5.15) \text{ m}$ receives it from the pumps and discharge it into a 3 m gravity sewer which runs for approximately 13 km reaching Al-Rustamyia WWTP. Ten sewage pumps are in Al-Habibia SPS, four of capacity of $(1.5) \text{ m}^3/\text{sec}$, four of $(1) \text{ m}^3/\text{sec}$ and two of $(0.5) \text{ m}^3/\text{sec}$ as shown in Fig. 2.

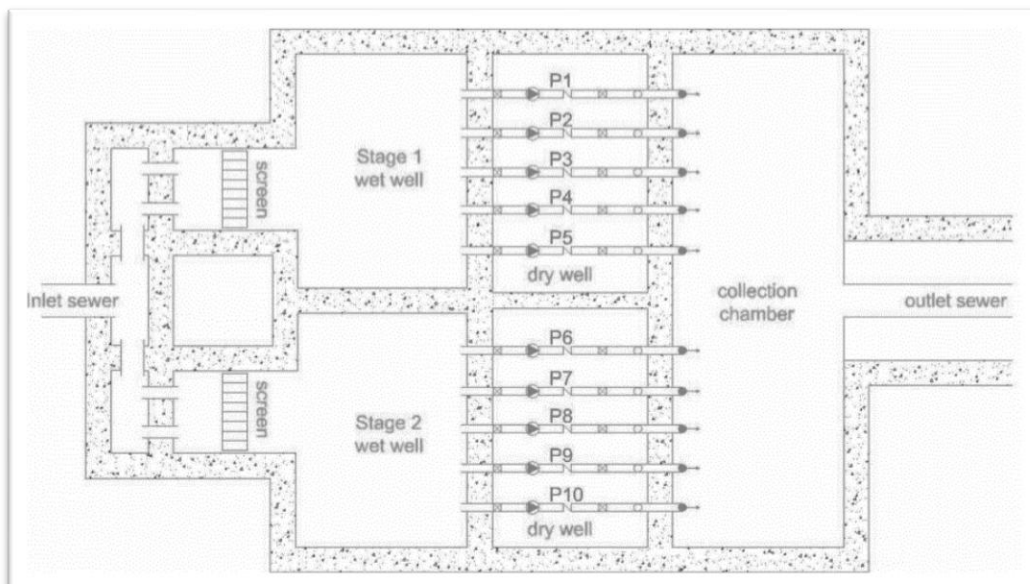


Figure 2. Al-Habibia sewage pump station layout.

2.2 Data collection

In this research, monthly data were collected for three years (2014, 2015 and 2016) for the concentrations of physical and chemical properties of wastewater i.e. (TSS, BOD, COD, PH, Cl) and the flow rates influent to the WWTP. Data were taken for the raw sewage entered to the WWTP. Excel 2013 and IBM SPSS 20 software were used for data analysis. The multilayer prediction artificial neural network analysis was performed by IBM SPSS 20 software.

3. MATHEMATICAL MODELLING

3.1 Artificial neural network (ANN)

A neural network is processor consist of several parameters to process the inputs with their interconnections. It contains a many building blocks, the most important ones are: Input layer, hidden layer, and output layer. These three layers are linked in a feed forward way were each square represents input data such as organic and sediment load as illustrated in **Fig. 3**. To expect the outcome information from input data, the neural networks could be used depend on simulates operation of human nervous time. The following formula could be used to normalize the input and output data, **Jacobson, 2013**.

$$x_{norm} = \frac{x_i - x_{min}}{x_{max} - x_{min}} \quad (1)$$

Where: x_{norm} is the normalize rate, x_i is the original information, x_{max} and x_{min} , is the maximum and minimum values respectively.

3.1.1 Ann Input Parameters Selection

The major aspect in neural network is the selection of input parameters. Hence, great consideration of input variable should be taken in account when the ANN structure has been used in order to provide effective results and better understanding of the problems. The input variables used in this research are influent flow rate, BOD, COD, TSS, PH, and CL as shown in **Fig. 4**. Those parameters have an important effect on the presentation of an ANN, and to make ANN work effectively.

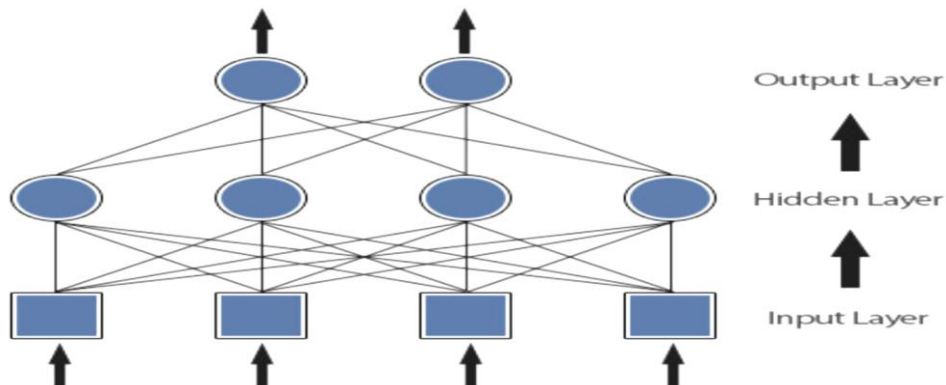


Figure 3. Simple feed-forward neural network.

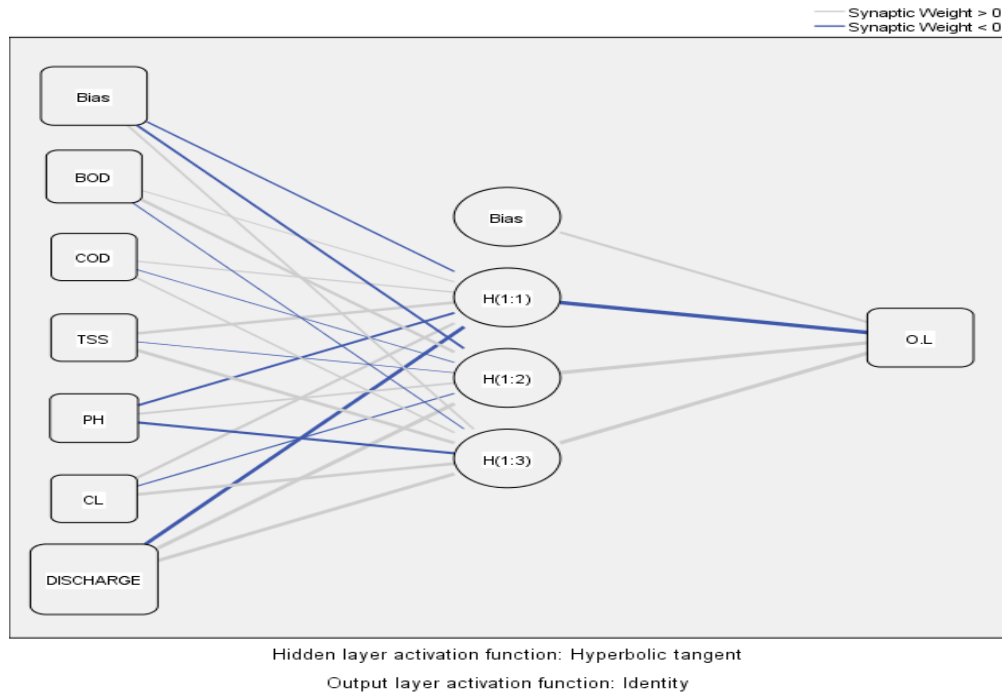


Figure 4. Inputs parameters for ANN.

3.2 Multiple Linear Regression (MLR)

The MLR methods are used to approximate the linear relation between single definite dependent variable of organic and sediment loads with the group of quantitative independent variables of raw sewage specifications. The raw sewage group parameters are used as independents variables in MLR linear equation do calculate the functions of classification as follow, **Hamada, et al., 2018**:

$$Y_i = A + a_1x_1 + a_2x_2 + \dots + a_nx_n \quad (2)$$

Where Y_i : Represents the function of classification when $i = 1$ to j (number of condition classes),
 X : Represents the independent variables (1 to n), a_i : Represent the coefficients of classification
and A : represent the offset

4. RESULTS AND DISCUSSION

4.1 Raw sewage flow assessment

The comparison between yearly performances of AL-Habibia SPS for influent raw sewage for the physical parameter (i.e. TSS) is shown in **Fig. 5**, also the yearly changes of the chemical parameters (i.e. BOD and COD) shown in **Fig. 6**, and **Fig. 7** for the Chloride parameter.

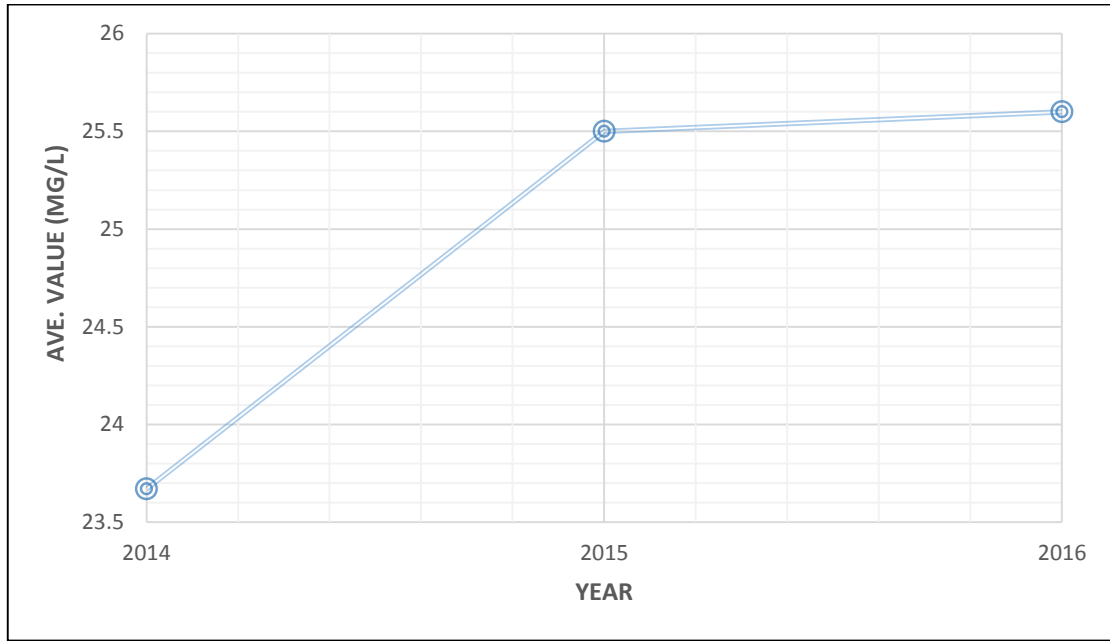


Figure 5. Yearly variation of TSS.

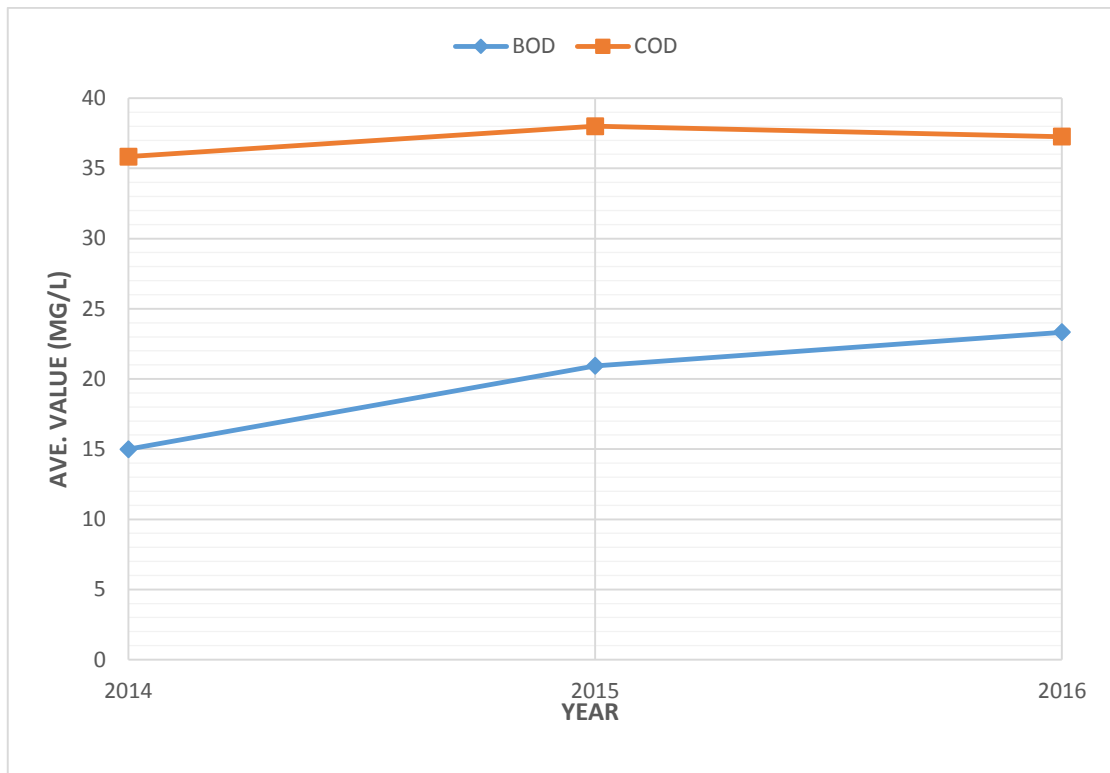


Figure 6. Yearly variation of BOD, COD.

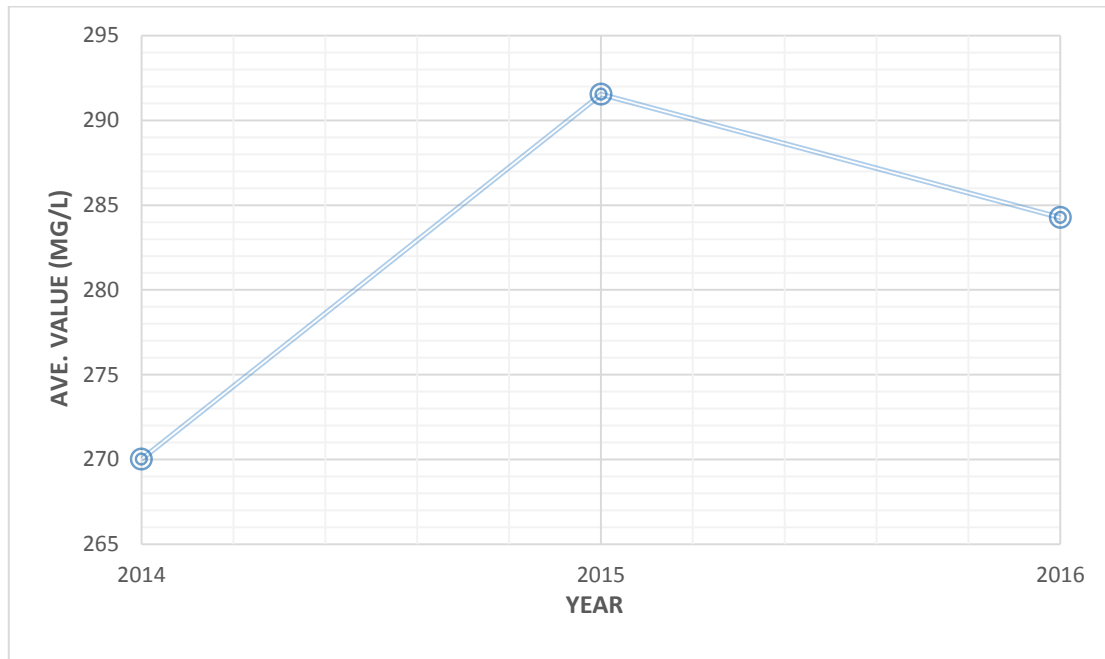


Figure 7. Yearly variation of CL

Fig.5, 6 and 7 indicate that the concentration of the physical and chemical in the wastewater in AL-Rusafa side of Baghdad increasingly with time and this cause based on the population growth, usual bad habits and the deterioration of the sewer network.

In addition, **Fig.5** shows that the total suspended solid increase at year 2015 because the high rain intensity at this year and drag more particles to the sewerage system and **Fig.7** indicate infiltration saline groundwater or discharge of chloride bearing wastes. Also the BOD₅/COD ratio is presented as some literature sources give such information, when ratio BOD₅/COD > 0.5, **Syed, 1998**, then the wastewater is fairly biodegradable and can treated biologically.

4.2 Data modelling processing

2.4.1 ANN

The neural network consists of 47 measured values in the raw sewage characteristics as a set of data. To find a set of model parameters that enables the model with given function form with efficient presentation, many training in ANN has been prepared with desired input and output relation. In one set, the 47 readings are combined to examine the possibility for developing a neural network model for predicting the organic and sediment loading. The ANN function model in Equation (4) and the correlation coefficient (R^2) was 99.6 %. Results showed that influent discharge rate have more effect on organic and sediment loading predicting to other parameters as shown in **Fig. 8**.

$$Y = 4.04 * 10^{-4} + 0.99 x \quad (3)$$



That's mean the changing of the influent sewage flow rate(x) can predict the pumping performance during dry and wet weather flow. The details parameters of proposed model are illustrated in **Table 2 and 3** for the estimation of hidden and output layers of ANN.

Table 2. Prediction parameters of output and hidden layers.

Predictor		Predicted			
		Hidden Layer			Output Layer
		H(1:1)	H(1:2)	H(1:3)	O.L
Input Layer	(Bias)	-.083-	-.161-	.100	
	BOD	.016	.360	-.013-	
	COD	.065	-.011-	.083	
	TSS	.385	-.002-	.399	
	PH	-.169-	.117	-.322-	
	CL	.325	-.043-	.387	
	DISCHARGE	-.569-	.639	.612	
Hidden Layer	(Bias)				.215
	H(1:1)				-1.669-
	H(1:2)				1.357
	H(1:3)				1.661

Table 3. Prediction parameters of output and hidden layers.

Predictor		Predicted		
		Hidden Layer		Output Layer
		H(1:1)	H(1:2)	S.L
	(Bias)	-.074-	-1.118-	
	BOD	.032	.034	
	COD	.010	.104	



Input Layer	SS	-.252-	.016	
	PH	-.064-	-.109-	
	CL	-.058-	-.246-	
	Discharge	-.558-	1.296	
Hidden Layer	(Bias)			1.400
	H(1:1)			-1.338-
	H(1:2)			1.813

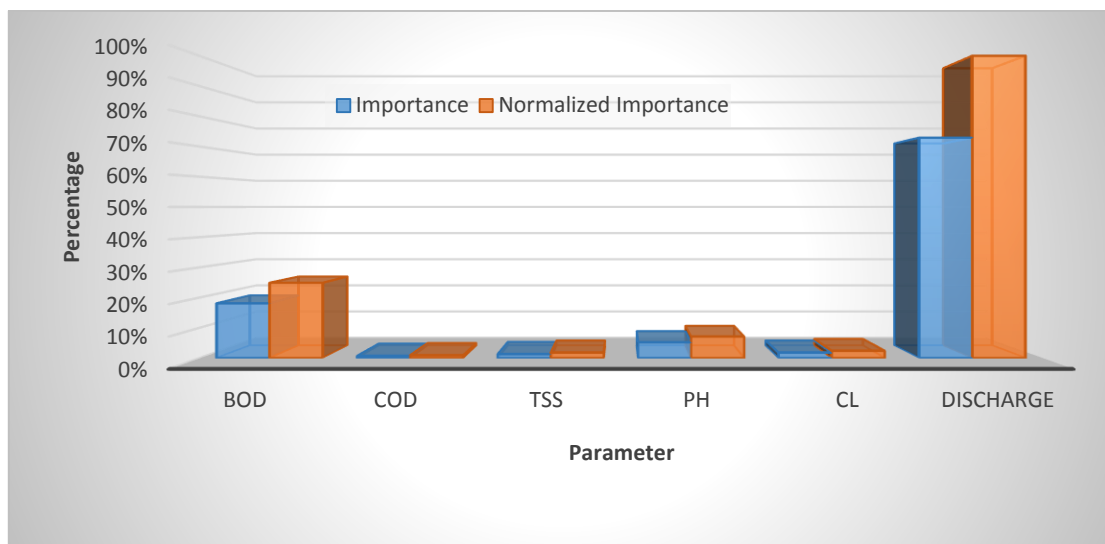


Figure 8. Independent Variable Importance.

2.4.2 MLR

The data set available for 47 measured values in the raw sewage characteristics as a set of data. SPSS regression tool is used adopting the stepwise procedure in the variable selection progression; this resulted in **Table 4**. Results showed the maximum coefficient of determination (R^2) of 99.8 % and 99.9% for the sediment and organic loading respectively.

Table 4. MLR model results

Target	Model	R	R^2	Std. Error of the estimate	function
Organic Loading	2	99.9	99.8	0.066	$Y_o = -1.47 + 0.016Q + 0.09BOD$
Sediment Loading	2	99.9	99.9	0.069	$Y_s = -2.329 + 0.026Q + 0.091TSS$



4.3 CONCLUSIONS

This paper presented the implication of sewage in Al-Habibia sewage pump station which utilize efficient prediction for the future has been suggested and improved. The development of ANN model to estimate the organic and sediment load in Al-Rusafa side of Baghdad (AL-Habibia SPS). The suggested models have been examined and evaluated on monthly sewage performance and influent discharge measurements over a period three years. Over the range of data size used in evaluation and examine, the development of ANN model to predict the diverse error efficiently is considered as robust tool nowadays. Better predictive and high capability could be resultant in this model in case of more data have been collected. However, the ANN and MLR techniques considers a valuable in sewage pump station performance prediction, but the ANN could be more suitable to provide efficient performance by capturing the non-linear weakening relation between inputs and outputs. For future development, the observations documentation of all collected data could support the reviewers of pump station systems performance as enough source of information.

5. ABBREVIATIONS:

SPS	Sewage Pump Station
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
TSS	Total Suspended Solids
ANN	Artificial neural network
MLR	Multiple Linear Regression
Y_o	Organic Loading
Y_s	Sediment Loading
WWTP	Waste Water Treatment Plant

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