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Prediction of Municipal Solid Waste Generation Models Using Artificial Neural Network in Baghdad city, Iraq

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ABSTRACT

The importance of Baghdad city as the capital of Iraq and the center of the attention of delegations because of its long history is essential to preserve its environment. This is achieved through the integrated management of municipal solid waste since this is only possible by knowing the quantities produced by the population on a daily basis. This study focused to predicate the amount of municipal solid waste generated in Karkh and Rusafa separately, in addition to the quantity produced in Baghdad, using IBM SPSS 23 software. Results that showed the average generation rates of domestic solid waste in Rusafa side was higher than that of Al-Karkh side because Rusafa side has higher population density than Al-Karkh side. The artificial neural networks show a high coefficient of determination between the predicted and observed domestic solid waste, with R^2 value reaching to 0.91, 0.828 and 0.827 for Al-Karkh, 0.9986,0. 9903 and 0.9903 for Rusafa side, and 0.9989, 0.9878 and 0.9847 in Baghdad city, and also, these models were used to estimate the generation of municipal solid waste for short period with highly efficient which assistance in planning to design landfills sites.

Key Words: Baghdad municipalities, Karkh, Rusafa, municipal solid waste, ANN

التنبؤ بنماذج توليد النفايات الصلبة البلدية باستخدام الشبكة العصبية الاصطناعية في مدينة بغداد، العراق

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الخلاصة

نظرا لأهمية بغداد بوصفها عاصمة للعراق ومركز اهتمام الوفود بسبب تاريخها الطويل، فمن الضروري الحفاظ على بيئتها. ويتحقق ذلك من خلال الإدارة المتكاملة للنفايات الصلبة، لأن ذلك لا يمكن إلا إذا كنا قادرين على معرفة الكميات التي ينتجها السكان على أساس يومي. لهذا السبب، تم التركيز في هذه الدراسة على إيجاد نماذج رياضية للتنبؤ بكمية النفايات الصلبة المتولدة في الكرخ والرصافة بشكل منفصل، بالإضافة إلى الكمية التي تنتجها مدينة بغداد باستخدام برنامج IBM SPSS 23. وأظهرت النتائج أن متوسط معدلات توليد النفايات الصلبة المنزلية في الرصافة كان أعلى من الكرخ لأن جانب الرصافة له كثافة سكانية أعلى من الكرخ. واستخدمت الشبكات العصبية الاصطناعية للعثور على النماذج المطلوبة حيث أظهرت النتائج وجود قيم ارتباط عالية لكل نموذج تم التنبؤ به . وقد أظهرت نتائج الشبكات العصبية الاصطناعية قيم ارتباط عالية لكل نموذج متوقع، حيث تصل قيمة R^2 إلى 0.91 و 0.828 و 0.827 للكرخ و0.9903 و 0.9980 و 0.9903 لجانب الرصافة و 0.9989 و 0.9878 و 0.9847

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لمدينة بغداد كما يمكن استخدام هذه النماذج لتقدير توليد النفايات الصلبة البلدية لفترة قصيرة بكفاءة عالية والتي تساعد في التخطيط لتصميم مواقع مدافن القمامة.
الكلمات الرئيسة: بلديات بغداد, الكرخ, الرصافة, النفايات الصلبة البلدية, الشبكات العصبية الاصطناعية.

1. INTRODUCTION

Municipal Solid waste is an expression used to refer to the useless or unwanted solid materials resulted from commercial, industrial and residential activities. Solid waste can be categorized according to its ancestry into (domestic, demolition and construction, commercial and industrial), according to the degree of hazard into it (infectious, toxic, nontoxic, flammable, radioactive, etc), and according to its contents into (organic material, paper, glass, plastic, metal, etc.), **Chabuk, 2016.** The significant factors of the massive growth in municipal solid waste quantities are social improvements in urban areas, economic growth, changing the lifestyle of urban residents, migration of rural people to urban areas, etc., **Suthar** and **Singh, 2014**. The solid waste quantities are increased as the population spending power increases, especially, due to the excess food that is thrown away instead of reserved for another day, **Hadi, 2014.** The per capita solid waste generation rate in urban residential areas of the developing countries is lower than that of the developed countries, **Ahsan, et al., 2014.**

Solid waste management involves all activities that should minimize the impacts of solid waste on the environment, aesthetic and public health. Non-scientific disposal practices that neglect the waste without control at the disposal sites leading to attract fleas, birds, rodents, etc., causing unhygienic conditions such as odor, greenhouse gases emissions, release of airborne pathogens and upbringing of disease vectors like mosquitoes, rats, flies and other lesions in the surroundings, **Suthar** and **Singh, 2014**. Poor solid waste management has negative impacts which may be more hazardous for those "living in third world countries". In third world countries, about 10% of the productive life of each person is lost due to waste-related diseases. According to that fact, the awareness of solid waste dangerous was increased on an international level, **Chabuk, et al., 2015**. In the developing countries, the local authorities are responsible for the solid waste management, but the low fiscal base and human resources capacity of the local authorities lead to provide limited services, **Walid, et al., 2016**.

This study aims to compute the municipal solid waste quantities generated in Karkh, Rusafa and Baghdad city by depending on amounts of domestic solid waste generated by each municipality and predict the generation rate model using the artificial neural network (ANN).

2. MATERIAL AND METHODS

2.1 Study area

Baghdad, the capital of Iraq and one of the most important Arab cities in the Middle East. Baghdad is divided into two parts Rusafa and Karkh as shown in **Plate 1**. Rusafa located on the east side of the city is extended along from Adhamiya in the North-West side to Jadriya in the South- East, while Al-Karkh is located at the West side of the city. Rusafa consists of eight municipalities, Adhamiya, Shaab, New Baghdad, Al-Ghadeer, Rusafa, Sadr 1, Sadr 2 and Karada while Al-Karkh municipalities are Rasheed, Al-Mansour, Karkh, Al-Doura, Kadhimiya, and Shula. The location, area, population, and density of each municipality are stated in **Table 1**. Baghdad's population was collected and the growth rate for the period (2009-2016) from Mayoralty of Baghdad/Office of Municipal Administrative.

2.2 Data collection and analysis

In this research, the data were collected from different government references as the municipal administrative office, the Statistics Division in the Department of Planning and Follow-up, and the Department of Statistics in the Municipality of Baghdad. The data includes the amounts of municipal solid waste of each municipality from 2004 to 2016, the population of Baghdad city and it is arranged in tables using Microsoft Office Excel 2016, and then IBM SPSS 23 software for statistical analysis.

3. MUNICIPAL SOLID WASTE GENERATION RATE

3.1 Global generation rate

The municipal solid waste generation rate is usually expressed in kg/capita/day. The unit of measurement can be easily applied to household waste, where the per capita value is multiplied by the number of population to get the total amount. Domestic solid waste represents the largest proportion of waste generated in urban areas, **Hadi, 2014**. Nowadays, the amount of solid waste is increasing as a result of global urbanization. In 1990, the amount of municipal solid waste that generated globally was about 1.3×10^9 ton, and at the present time, the annual generation rate is about 1.6×10^9 ton, **Márqueza, et al., 2008**. The municipal solid waste generated by the urban population of Asia is 760×10^3 ton/day and it is expected to rise to 1.8×10^6 ton by 2025, **Walid, et al., 2016**. The annual solid waste generated in sub-Saharan Africa is about 62 million tons/year and about 270 million tons/year in East Asia and Pacific Region. This amount is influenced by the solid waste generated in China, where it contributes with 70% of the total regional. Also, the annual solid waste generated in Eastern and Central Asia is at least 93 million tons, and 160 million tons is annually generated by the Caribbean and Latin America, **Saidou** and **Aminou, 2015.**

3.2 Local generation rate in Iraq

Iraq has a population more than 32 million inhabitants. A deterioration in the solid waste management issue of Iraq resulted from the growing population and the quick economic growth which causes an increase in the individual incomes in addition to recurrent wars and the instability caused by sectarian conflicts. Decades of war, instability, sanctions, and mismanagement of solid waste have contributed to dispose of waste in irregular ways, **Chabuk, et al., 2015**. The countries were classified according to their average yearly income per capita, where the low-income countries have the lowest solid waste generation rates between 0.1-0.5 kg/capita/day, in middle-income countries 0.5-1.1 kg/capita/day and in high-income countries have the highest rates that are above 1.1 kg/capita/day, **Márqueza, et al., 2008**. Based on the reports and studies of Baghdad city, it is assumed that the solid waste generation rates in Baghdad range between 0.3-0.8 kg/capita/day, **Al-Samawi et al., 2008**. This rate differs from place to another, where it reaches 0.44 kg/capita/day in Kirkuk city, 0.42 kg/capita/day in Najaf governorate and 0.496 kg/capita/day in Mousel city**, Al-Anbari, et al., 2016**. In Hilla districts, the generation rate was 0.93 kg/capita/day for the year 2012 and expected to reach 1.06 kg/capita/day in 2016, **Hadi, 2014**.

4. ARTIFICIAL NEURAL NETWORKS (ANNs)

Artificial Neural Networks are cellular information processing method designed and developed based on the perceived concept of the human brain, adding to its neural system, **Jahandideh, et al., 2009**. This network consists of very high interconnecting processing elements operating in parallel called neurons. The inspiration for these elements comes from biological nervous systems. The elements' connections largely to determine the function of the network. A layer is a name

given to a subclass of the processing element. The input layer is the first layer and the output layer is the last, the layer(s) located between the input and output layer are called hidden layer(s), **Al-Shayea** and **El-Refea, 2013**. **Fig. 1** shows the structure of multilayer Feedforward Neural Network. Every unit takes its input then applies its activation function. Researchers have been using many nonlinear functions as activation functions, but the two popular choices for these functions are sigmoid functions Eq. (1) and the threshold function Eq. (2), **Warner and Misra, 2012.** Given enough data and complexity, artificial neural networks can train the network to model every relationship between dependent and independent variables, so ANNs are applied to a wide range of problems that are hard to define, and understand, **Zade and Noori, 2007.**

$$y_{\text{netinput}} = \frac{1}{1+e^{-\text{netinput}}} \quad (1)$$

$$\theta(\text{netinput}) = \begin{cases} 1 & \text{if netinput} \geq 0 \\ 0 & \text{otherwise.} \end{cases} \quad (2)$$

5. RESULTS AND DISCUSSION

In general, the trend line of the population growth rate in Baghdad city increased during the period above as shown in **Figs.2** and **3** which increases the municipal solid waste quantity. The average weights of municipal solid waste were calculated in the terms of (kg/year), depending on the average population of each municipality as shown in **Table 1,** the average generation rates in (kg/capita/year) were computed as shown in **Fig. 4**. Rusafa municipality has the maximum generation rate (918.541) kg per capita per year due to the fact that this side of Baghdad city consists of commercial area, and the solid waste generated contains cardboard, wood, boxes, plastic materials, food residue, etc. In addition, solid waste is also generated from its residential areas where the minimum generation rate was in Al-Gadeer municipality (247.552) kg per capita per year. The flocculation in the generation rate shown in **Fig. 4** is due to the difference of population density and the nature of municipalities (commercial, industrial or residential area). The average generation rates for Rusafa side, Al-Karkh side, and Baghdad city were 473.303, 379.457, and 433.083 kg/capita/year respectively, as where Rusafa side is the most waste-generating.

The amounts of municipal solid waste generated by each municipality help to compute the municipal solid waste quantities generated in Al-Karkh, Rusafa and Baghdad city and model predicted using multilayer predication neural network. The observed values of Al-Karkh side and Rusafa side were used in the prediction of Baghdad domestic solid waste. **Figs. 5, 6** and **7** show the relation between the predicted and observed domestic solid waste. The artificial neural networks appear a high coefficient of determination between the predicted and observed domestic solid waste, with R^2 value reaching to 0.91, 0.828 and 0.827 for Al-Karkh side when domestic solid waste used in terms of (ton/year), (ton/capita/year) and (ton/km^2/year) as shown in **Fig.5**. For Rusafa side, R^2 values were 0.9986,0.9903 and 0.9903 for domestic solid waste used in terms of (ton/year), (ton/capita/year) and (ton/km^2/year) as shown in **Fig.6**. The same procedure is applied for Baghdad city the value of R^2 was equal to 0.9989, 0.9878 and 0.9847 in (ton/year), (ton/capita/year) and (ton/km^2/year) respectively, as shown in **Fig. 7**.

6. CONCLUSION

Solid waste quantity generation varies in Baghdad due to population size, density and life style between Al-Rusafa and Al-Karkh sides. The data from the municipalities in Baghdad showed that the average generation rates of domestic solid waste in Al- Rusafa side were higher than that of Al-Karkh side. High rates in Al-Rusafa side is due to higher population density and most important trade centers are located on this side (like Shorja, Senak and Jamelaa). The data from the municipalities of the two sides in Baghdad were used to build ANN models to predict the generation rates of municipal solid waste. The developed ANN models gave good results as the R^2 value was high. These models can be used to estimate the amount of municipal solid waste generated in different parts in Baghdad which could help in planning and designing landfills sites.

REFERENCES

- Ahsan, A., Alamgir, M., El-Sergany, M. M., Shams, S., Rowshon, M. K., and Daud, N. N. Nik 2014, *Assessment of Municipal Solid Waste Management System in a Developing Country*. Chinese Journal of Engineering, Volume 2014, Article ID 561935, 11 pages, Hindawi.
- Al-Anbari, M.A., Thameer, M.Y., Al-Ansari, N. and Knutsson, S., 2016, *Estimation of Domestic Solid Waste Amount and Its Required Landfill Volume in Najaf Governorate-Iraq for the Period 2015-2035*. Engineering, Vol. 8, PP. 339-346.
- Al-Samawi, Adnan A., Zboon, Abdul Razzak T. and Alnakeeb, Aumar, 2009, *Estimation of Baghdad Municipal Solid Waste Generation Rate.* Eng. & Tech. Journal, Vol.27, No.1.
- Al-Shayea, Qeethara, and El-Refea, Ghaleb, 2013, *Predicting the Effects of Medical Waste in the Environment Using Artificial Neural Networks: A Case Study.* IJCSI International Journal of Computer Science Issues, Vol. 10, Issue 1, No 3, PP. 258-261.
- Chabuk, A., Al-Ansari, N., Hussain, H.M., Knutsson, S. and Pusch, R., 2015, *Present Status of Solid Waste Management at Babylon Governorate, Iraq*. Engineering, 7, 408-423.
- Chabuk, A., and Ali Jalil, 2016, *Analysis of Landfill Site Selection-Case Studies Al-Hillah and Al-Qasim Qadhaas, Babylon, Iraq*. Luleå University of Technology, Department of Civil, Environmental and Natural Resources Engineering.
- Jahandideh, Sepideh, Jahandideh, Samad, Asadabadi, Ebrahim Barzegari, Askarian, Mehrdad Movahedi, Mohammad Mehdi, Hosseini, Somayyeh, and Jahandideh, Mina, 2009, *The Use of Artificial Neural Networks and Multiple Linear Regression to Predict Rate of Medical Waste Generation.* Waste Management, Vol. 29, Issue, 11, PP. 2874-2879.
- Márqueza, Ma. Ysabel, Ojedaa, Sara, Hidalgo, Hugo, 2008, *Identification of Behavior Patterns in Household Solid Waste Generation in Mexicali's City: Study Case.* Resources, Conservation and Recycling, Vol. 52, PP. 1299–1306.
- Mayoralty of Baghdad/Office of Municipal Administrative Agent.
- Moftah, W.A.S., Marković, D., Moftah, O.A.S. and Nesseef, L., 2016, *Characterization of Household Solid Waste and Management in Tripoli City—Libya*. Open Journal of Ecology, Vol. 6, PP. 435-442.
- Saidou, H. and Aminou, S., 2015, *Solid Waste Management in the Town of Maradi in Niger Republic.* Journal of Environmental Protection, Vol. 6, PP. 359-373.

- Hadi, Nabaa Shakir, 2014, *Estimation of Municipal Solid Waste Generation Rate (Case Study of Hilla City.* Journal of Kerbala University, Vol. 12, No.1, Scientific. 2014.
- Suthar, Surindra and Singh, Pavitra, 2015, *Household Solid Waste Generation and Composition in Different Familysize and Socio-Economic Groups: A Case Study* . Sustainable Cities and Society, Vol. 14, PP. 56–63.
- The Iraqi Ministry of Planning / The Central Statistical Device.
- Warner, Brad and Misra, Manavendra, 2012, *Understanding Neural Networks as Statistical Tools.* The American Statistician, November 1996, Vol. 50, No. 4.
- Zade, Jalili Ghazi, M. and Noori, R, 2008, *Prediction of Municipal Solid Waste Generation by Use of Artificial Neural Network: A Case Study of Mashhad.* Int. J. Environ. Res., Vol. 2, No. 1, PP. 13-22.

Plate 1. A map of Baghdad city.

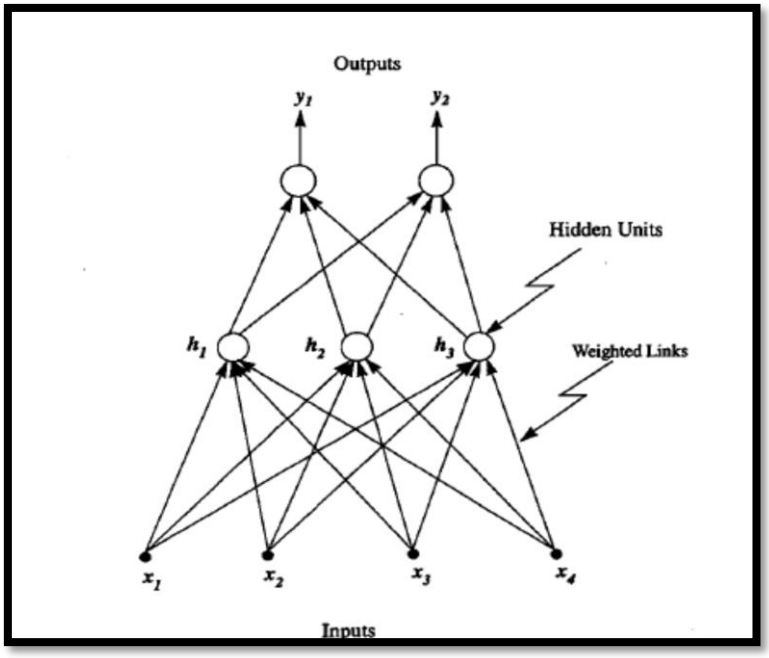


Figure 1. Schematic representation of a multilayer feedforward neural networks.

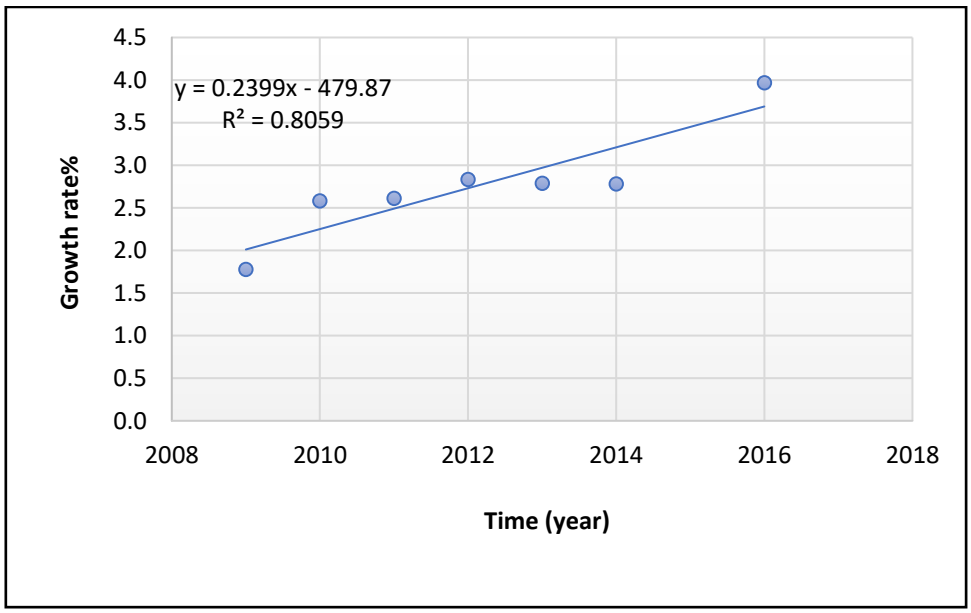


Figure 2. The annual growth rate in Baghdad city.

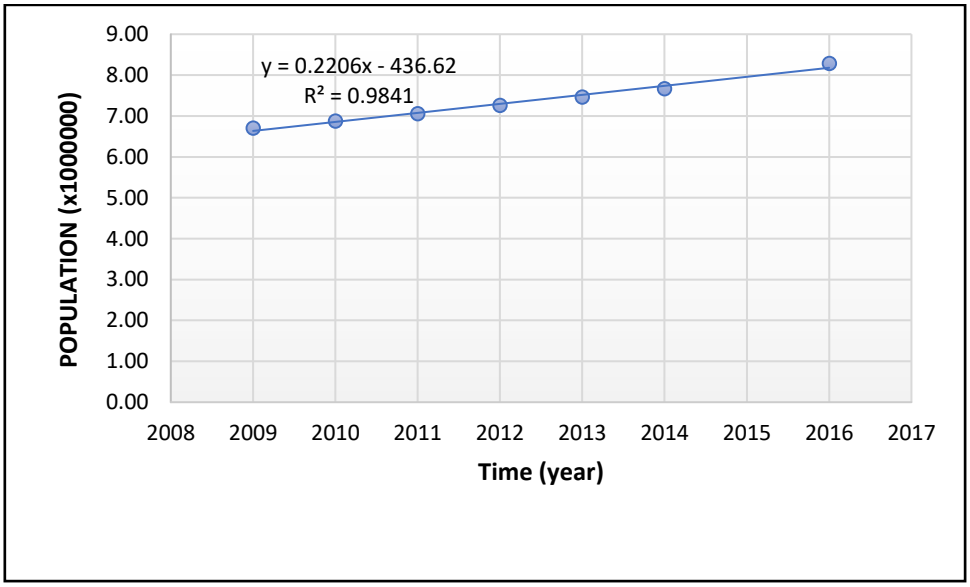


Figure 3. The population of Baghdad city.

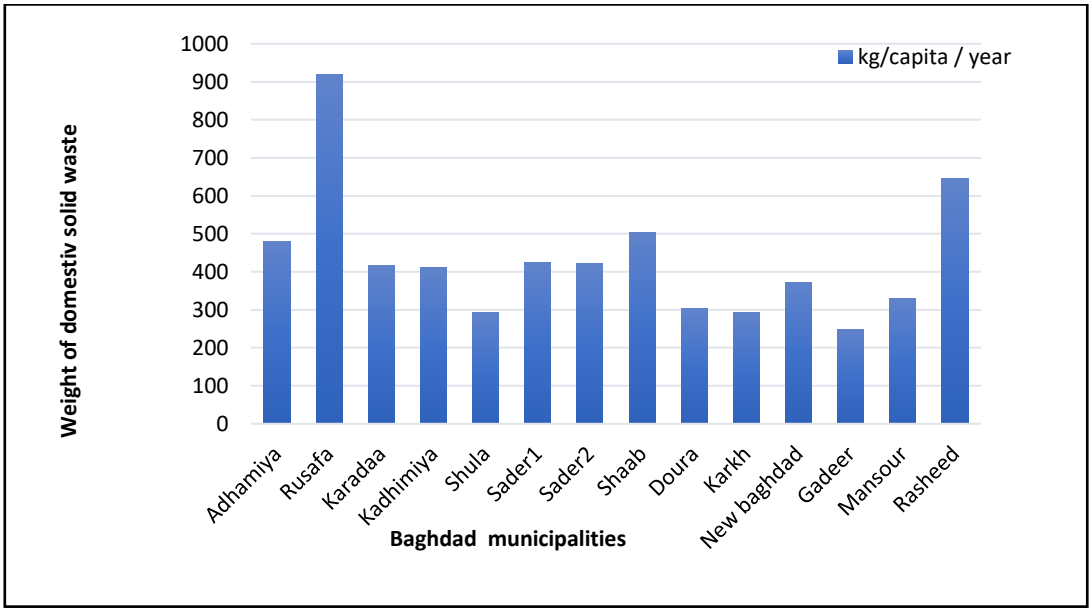
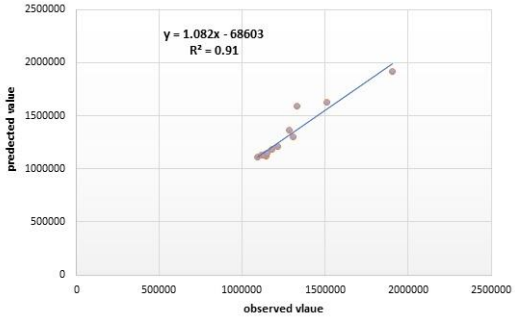
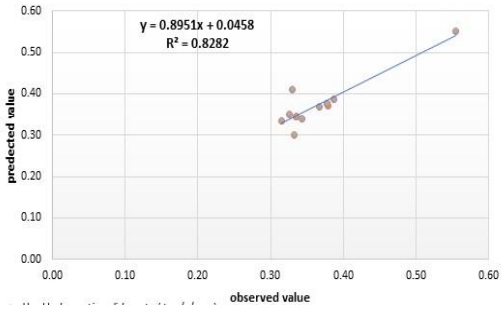


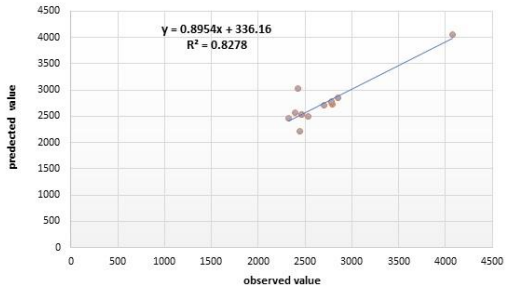
Figure 4. Annual domestic solid waste generation rates (kg/capita/year).



a) Solid waste (ton/year)

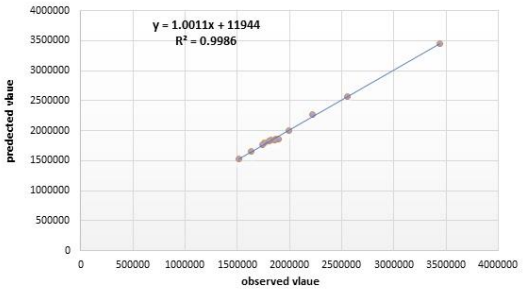


b) Solid waste (ton/ capita/year)

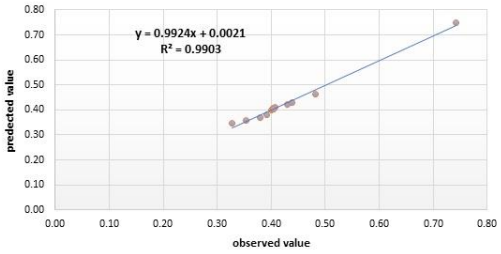


c) Solid waste (ton/km^2/year)

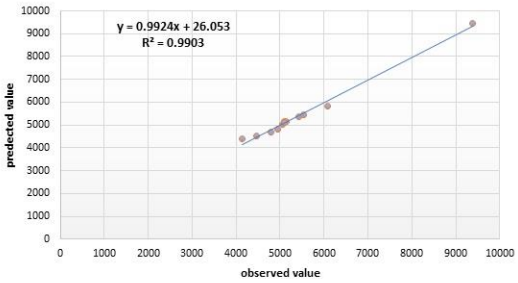
Figure 5. Observed and predicted domestic solid waste for Al-Karkh side.



a) Solid waste (ton/year)

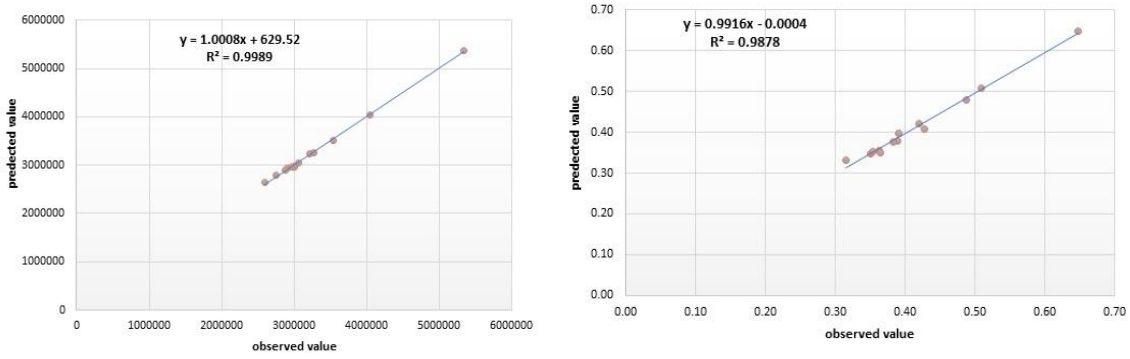


b) Solid waste (ton/ capita/year)

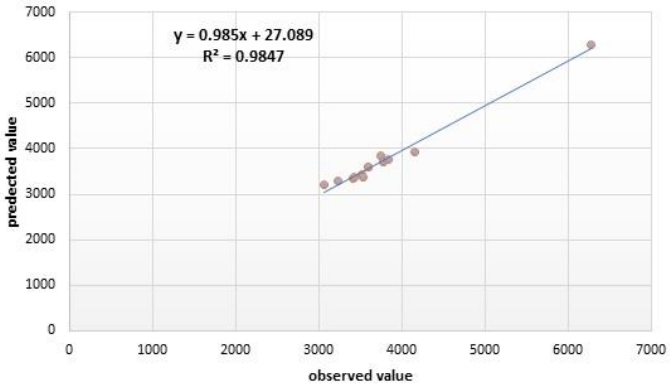


c) Solid waste (ton/km^2/year)

Figure 6. Observed and predicted domestic solid waste for Al-Rusafa side.



a) Solid waste (ton/year) **b)** Solid waste (ton/capita/year)



c) Solid waste (ton/km^2/year)

Figure 7. Observed and predicted domestic solid waste for Baghdad city.

Table 1. Description of the municipalities of Baghdad.

Side	Municipality	Locality	Location	Average Population	Area (km^2)	Density (capita/km^2)
AL-Karkh municipalities	Rasheed	48	Locality817, Alley 2	499838.3	130.6	3827.25
	Al-Mansour	57	Locality 615, Street 19	963990.7	105	9180.86
	Karkh	20	Locality 218, Building 112	300315	14.5	20711.38
	Kadhimiya	22	Locality 413, Alley 2, Building 16	529883.7	55.4	9564.69
	Doura	30	Locality840, Street 16	389803	83	4696.42
	Shula	26	Locality 452	800156	85	9413.6
	Average	/	/	580664.5	78.92	9565.7
AL-Rusafa municipalities	Al-Ghadeer	34	Locality 726, Alley 13	774284	51.5	15034.64
	Rusafa	45	Locality 127, Alley 29	326146.7	21.5	15169.6
	Sadr 1	31	Locality 512, Street 22	764589	31.3	24427.7
	Sadr 2	27	Locality 512, Street 22	699987.67	15	46665.8
	Shaab	33	Locality 321, Street 26	481969.7	98.6	4888.13
	Adhamiya	28	Locality 318, Street 31	512891.67	27.2	18856.3
	New Baghdad	46	Locality 729, Alley 17	762613.667	63.8	11953.2
	Karada	39	Locality101, Alley 18, Building 55	452394.7	69	6556.4
	Average	/	/	596859.64	47.24	17943.97
	Baghdad average	/	/	589918.8434	60.81	14353.28