ISSN 2303-4521
Periodicals of Engineering and Natural Sciences *Original Research*
Vol. 11, No. 3, May 2023, pp.39-45

Reliability of the Tigris River water treatment center in al-Rashidiyah-Baghdad by using Weibull distribution

Mohammed Jumaa Samih , Iqbal Mahmoud Alwan
University of Baghdad, College of Administration and Economics, Baghdad, Iraq

ABSTRACT

The research includes a study of analyzing and evaluating the reliability of turbidity removal and the amount of residual chlorine in the water in the Rashidiya water center located in Rashidiya-Baghdad-Iraq according to the permissible criteria for making decisions based on solid scientific foundations. Thus, water treatment centers in general need a reliable evaluation that helps in evaluating the output Water treatment centers according to the standards set for each center. The research aims to evaluate the reliability of the Rashidiya water center using the two-parameter Weibull distribution, where the distribution parameters were estimated using the least squares method using the (Matlab 2022) program. The chi-square test was used for Goodness of Fit at a significant level of 0.05, through the Easy Fit 5.5 professional program. It was found to be distributed according to the Weibull distribution, and descriptive statistics were calculated for each parameter, and it was found that the mean (and median) of the turbidity values (9.379), which is within the permissible limit, The mean (and median) chlorine values are (0.0279), which is also much less than the permissible limit. The efficiency scale was used to remove turbidity. It was found that the average efficiency of turbidity removal is 71.35%, which is a relatively acceptable level. However, it is necessary to increase the turbidity treatment to raise the level of efficiency. It was found through the Weibull distribution analysis that the value of reliability for the removal of turbidity is (0.99), and for the remaining amount of chlorine is (0.99). The research concluded that the Rashidiya water center is reliable during the research period. The research recommends evaluating all water treatment centers in Iraq in general, and in Baghdad in particular, periodically and at certain time periods. The research also recommends using the natural logarithm distribution as it is suitable for evaluation.

Keywords: Reliability, Efficiency, Weibull Distribution, Least Squares, the exceedance rate, chi-square test.

Corresponding Author:

Mohammed Jumaa Samih
University of Baghdad, College of Administration and Economics,
Baghdad, Iraq
Email: Mohammed.jumaa1201a@coadec.uobaghdad.edu.iq

1. Introduction

Reliability can be broadly defined for a water treatment plant as the probability that a plant will meet the maximum allowable limits of the treatment standards within a specified time[1]. or the purposes of processing[2] , whereby the Tigris River Water Treatment Center (in Rashidiya-Baghdad) will be absolutely reliable when the response to process efficiency is not compromised, ie when the limits set by targets or by environmental regulations are not violated. The treatment process fails when the required standards or initiation goals are exceeded[1] [3]. One of the most widely used methods for assessing reliability is using the Weibull distribution [4][5]. The Weibull distribution is a general probability distribution that can be used in assessing reliability and in assessing risk. for a Tigris River water treatment center, the reliability obtained must be compared with the instructions contained in the water law permit, if it turns out that the center is not reliable in the area of remediation, measures must be taken to identify and subsequently eliminate operational deficiencies. As there are many unknowns underlying the design and operation of water treatment plants, the risk of failure is always inevitable as water treatment plants must be designed with an acceptable level of risk or injury [1]. In order to determine the acceptable probability of failure, minimum reliability requirements should be defined. High expectations of lower quality processing can result in additional steps or more complex maintenance, the installation of advanced controls, and often an increase in the physical size of the process[2]. The site's water treatment center reliability in terms of depollution is affected by several factors dependent and independent of the operator; Among the most important of these factors are the wide variations in water quantity and quality, some of which do not depend on utility operators, such as the amount of rain falling, and the torrents that end in the Tigris River. In the Rashidiya Water Center, one of the most important factors that have a negative impact on the operation of the center and thus reduce reliability is rain, torrential rains and illegal discharge of sewage water.[2]

Al Rashidiya Water Center is located in the north of Baghdad, about 200 meters away from the Tigris River, with a design capacity of 2000 m3/h [6], as the project's work mechanism adopts the traditional treatment system, which includes drawing raw water from the river and then entering it into Relatively large ponds to be mixed with alum, after that the water is distributed to the sedimentation ponds, and then the water is transferred to the filtration ponds, where the depth of each basin ranges between 12-14 meters, a length of 4 meters, and a width of 5 meters, each basin consists of several Layers of gravel and sand of varying thickness. Then, the water is pushed into ground tanks, in which the final chlorine sterilization process takes place.[7]

The aim of this work was to evaluate the practical reliability of the Rashidiya water supply station located north of Baghdad using the Weibull distribution that analyzed the turbidity and the amount of residual chlorine in drinking water.

2. Methods

The study was conducted during the two years (2021-2022), starting from 2/2/2021 to 6/16/2022, on daily data measured according to modern devices for turbidity and chlorine parameters, where turbidity is measured before and after the treatment process, and the study relied on turbidity data after treatment only. Chlorine is measured after the treatment process to know the remaining amount of it in the treated drinking water, as it is used in the sterilization process.

The acceptable limits for discharged water after treatment are as follows [8][9]:

Turbidity: 15 NTU

Residual chlorine: 3 mg/L

The reliability of the Rashidiya water center was determined using the Weibull distribution, the Weibull distribution can be used when the failure rate[10] (the Exceedance Rate, in the case of water treatment plant) follows a monotonic trend [2]. The Weibull distribution is characterized by a probability density function[11]:

$$f(u) = \frac{\beta}{\alpha^{\beta}} u^{\beta-1} exp\left[-\left(\frac{u}{\alpha}\right)^{\beta}\right] \qquad , u \geq 0 , \alpha > 0 , \beta > 0. \qquad (1)$$

And the reliability function is given by the following formula [12]:

$$R(u) = exp\left[-\left(\frac{u}{\alpha}\right)^{\beta}\right] \qquad , u \geq 0, \alpha > 0, \beta > 0. \qquad (2)$$

The parameters of the Weibull distribution were estimated using the method of least squares (LS) [11][12], and through the Matlab 2022 program, the suitability of the Weibull distribution to the experimental data was evaluated according to EasyFit Professional 5.5 software.

The least squares method is one of the most important methods for estimating the reliability function because it reduces the square errors between the CDF of a given distribution and one of the nonparametric estimates of the CDF [12]. Then from equation (2) we get a linear relationship as follows:

$$Ln\left[-Ln\left(1 - F(u;\alpha,\beta)\right)\right] = -\beta Ln\alpha + \beta Lnu \qquad (3)$$

Now formula (3) can be written as a simple regression model $[y_j = a_\circ + b_\circ x_j + \varepsilon_j]$ as follows:

Let: $y_j = Ln[-Ln\left(1 - \hat{F}(u;\alpha,\beta)\right)]$, $x_j = Lnu_j$, $a_\circ = -\beta ln\alpha$, and $b_\circ = \beta$. (4)

The values of $(F(u;\alpha,\beta)$ can be estimated by the nonparametric method of experiment and by the formula:

$$\hat{F}(u;\alpha,\beta) = [(j - 0.5/n)\,, \quad j = 1,2,3 \ldots n] \qquad (5)$$

Estimators $(\hat{a},\hat{b})$ for the parameters of the regression model minimize the function[13]:

$$\rho(a,b) = \sum_{j=1}^{n}\left(y_j - a_\circ - b_\circ x_j\right)^2 \qquad (6)$$

Therefore, the estimates $\hat{a}_\circ, \hat{b}_\circ$ and of the parameters $a_\circ, b_\circ$ are given by:

$$\hat{b}_{\circ OLS} = \frac{n\sum_{j=1}^{n} y_j x_j - \sum_{j=1}^{n} y_j \sum_{j=1}^{n} x_j}{n\sum_{j=1}^{n} x_j^2 - \left(\sum_{j=1}^{n} x_j\right)^2}\text{, and }\hat{a}_{\circ OLS} = \frac{1}{n}\sum_{j=1}^{n} y_i - \hat{b}_{\circ OLS}\frac{1}{n}\sum_{j=1}^{n} x_j \qquad (7)$$

So the estimated distribution parameters will be: $\hat{\beta} = \hat{b}_{\circ OLS}$, $\hat{\alpha} = exp\left(\hat{a}_{\circ OLS}\right)$

And the estimated reliability function will be:

$$\hat{R}(t)_{OLS} = exp\left[-\left(\frac{u}{\hat{\alpha}_{OLS}}\right)^{\hat{\beta}_{OLS}}\right] \qquad (8)$$

Descriptive statistics were calculated based on the study data: mean, median, maximum and minimum values and standard deviation [14][15]. The turbidity removal efficiency was also calculated according to the following formula [1][3]:

$$eff = \left(1 - \frac{Turbidity_{out}}{Turbidity_{in}}\right) * 100 \qquad (9)$$

whereas:

$Turbidity_{out}$: Turbidity after treatment.

$Turbidity_{in}$: turbidity before treatment.

3. Results and discussion

3.1. The quality of the treated water of the Tigris River

Descriptive statistics on turbidity and chlorine were determined and the turbidity and chlorine values were close to the mean and median and close to acceptable standards according to the requirements[8]. In rare cases, some turbidity values were higher than the mean and median and exceeded the required standards. This is due to rainfall and torrential rains that changed the shape of the water of the Tigris where the highest turbidity value (59) on (December 24, 2021) was higher than the allowable value of. Table 1 shows the statistics of the analyzed parameters of the waters of the Tigris river.

Table 1. Pollution parameter statistics for turbidity and residual chlorine

Parameter	**Unit**	**Statistics**				
		Mean	**Median**	**Min**	**Max**	**St. Deviation**
Turbidity	Unity	9.376	9	3	59	2.7095
Chlorine	Mg/L	0.0297	0.03	0.02	0.04	0.002650292

3.2 Reliability of the Tigris River water treatment plant

The reliability of the Rashidiya water center with respect to turbidity and chlorine was determined using a Weibull distribution. Also, the chi-square test was used for Goodness of Fit at a significant level of $a = 0.05$. Table 2 shows the values of the distribution parameters and the chi-square test.

Table .2 the results of estimating the coefficients of the Weibull distribution, and the results of the chi-square test for the experimental data

Parameter	**Unit**	**Parameter Distribution**		**chi-square test**	
		$\boldsymbol{\alpha}$	$\boldsymbol{\beta}$	**Test value**	**P**
Turbidity	Unity	9.3796	2.8841	0.58357	0.99976
Chlorine	Mg/L	0.3059	19.2274	11.178	0.19182

Table 2 shows the estimations of the measurement and shape parameters of the Weibull distribution, which were estimated using the method of least squares. and the results of the chi-square test for the experimental data.

The reliability of reducing turbidity to the required standards (15 units) was (0.99) as shown in Figure 1, with a probability of failure (exceedance) (0.1). This means that a value equal to or less than (15 units) appeared about 494 times during the 500-day study period.

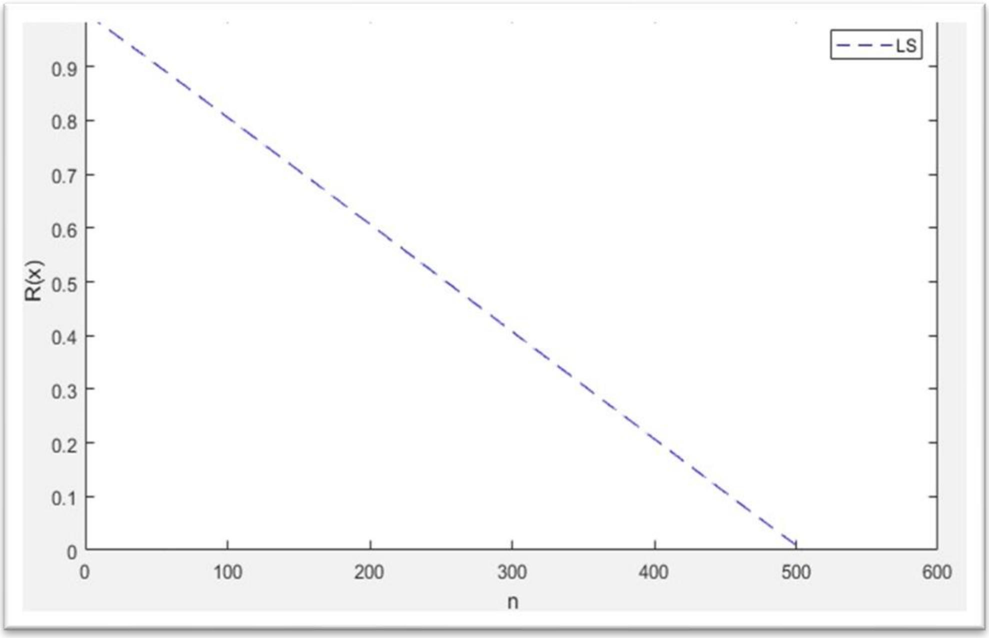

Figure 1.Turbidity reliability estimated using the least squares method

Figure 1 shows the reliability estimates using the least squares method for the turbidity values. The figure shows that the reliability values decrease with the increase in the turbidity values, as the highest reliability value was (0.99) at the lowest turbidity value, while the lowest reliability value was (zero) at the highest value of turbidity values.

The turbidity data has been drawn in a graph, and it has been shown from the drawing that the majority of the data falls within the permissible limit, and that some values fall outside the permissible limit, which is acceptable because the study period is relatively large, and the reason for this is due to rain and torrential rains that change the shape of the river water Tigris. Figure 2 shows the turbidity data graph.

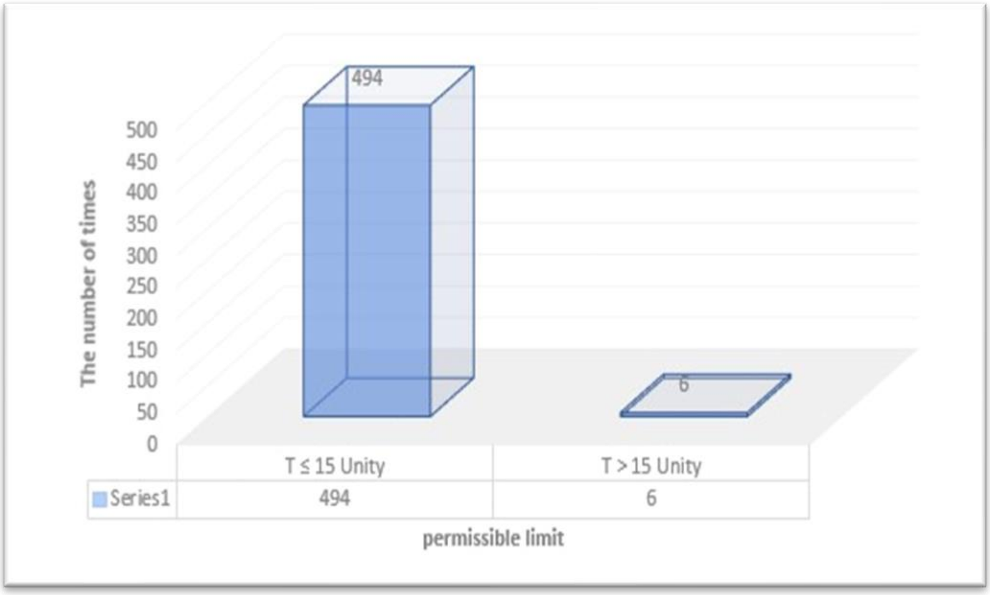

Figure 2. Graph of turbidity data

Figure 2 shows the graph of turbidity values, and shows that (494) of the total values did not exceed the permissible limit for treatment, while there were (6) values of the total values that exceeded the permissible limit for treatment.

The reliability of reducing chlorine to the stipulated standards (3 mg/L) was (0.99) as shown in Figure 3. With a probability of failure (exceedance) (0.1). This means that a value equal to or less than (3mg/L) appeared about 500 times over the 500-day study period.

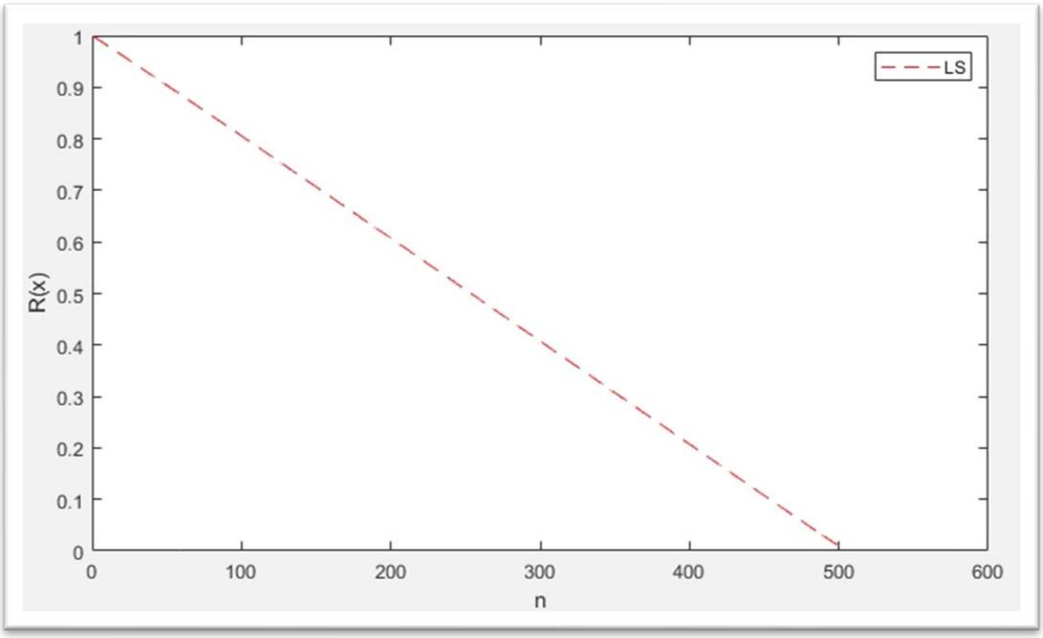

Figure 3. Chlorine reliability estimated using the least squares method

Figure 3 shows reliability estimates using the least squares method for chlorine values, and it appears from the figure that the reliability values decrease with increasing chlorine values, as the highest reliability value was (0.99) at the lowest value of chlorine values, while the lowest reliability value was (zero) at The highest value of turbidity values.

Chlorine data was plotted in a graph, showing that all chlorine values did not exceed the permissible limit of 3mg/L. Figure 4 shows a graph of the chlorine data.

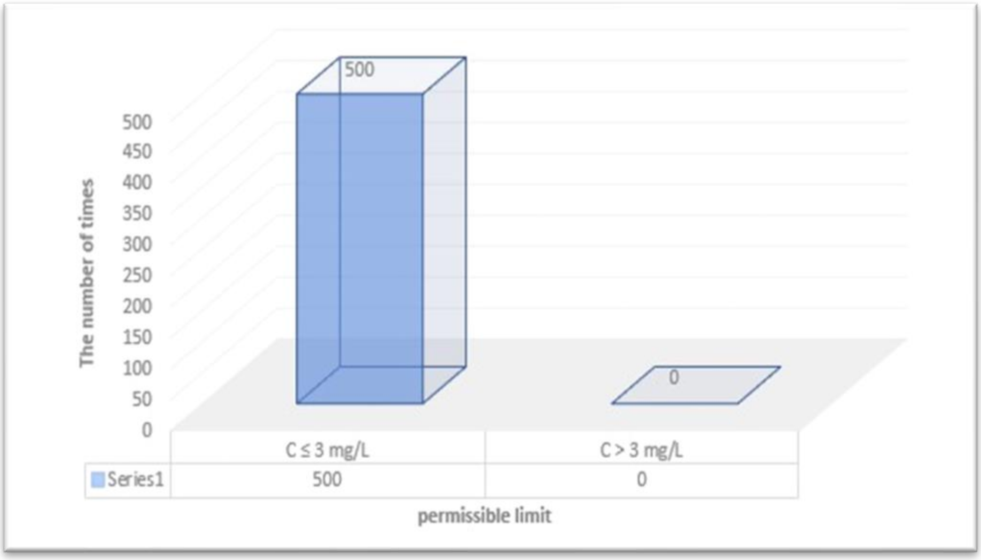

Figure 4. Chlorine data graph

Figure 4 shows a graph of chlorine values and shows that all values were less than the allowable limit for treatment, as there were no cases of excess in the study period of (500) days.

4. Conclusions and recommendations

According to the results of the reliability analysis conducted for the Rashidiya Water Center, the Weibull distribution analysis showed the following: The reliability value for turbidity was (0.99). and chlorine was (0.99). The mean turbidity value was (9.376 NTU). The mean chlorine value was (0.0297 mg/L), which are less than the permissible limit. The reliability of the Rashidiya water center during the study period was acceptable according to the criteria set for treatment.

The study recommends evaluating all water treatment standards in Al-Rashidiyah water center specifically - since the center measures turbidity and the amount of residual chlorine only in Iraq in general, and conducting the evaluation according to international standards for river water treatment and comparison with them. The study recommends evaluating water treatment standards according to the normal logarithm distribution, as it is also suitable for evaluation.

Declaration of competing interest

The authors declare that they have no any known financial or non-financial competing interests in any material discussed in this paper.

Funding information

No funding was received from any financial organization to conduct this research.

References

[1] S. Oliveira and M. Sperling, “Reliability analysis of wastewater treatment plants,” *Water Res*, vol. 42, no. 4–5, pp. 1182–1194, 2008.

[2] P. Bugajski and E. Nowobilska-Majewska, “A Weibull Analysis of the Reliability of a Wastewater Treatment Plant in Nowy Targ, Poland,” 2019.

[3] M. Marzec *et al.*, “The efficiency and reliability of pollutant removal in a hybrid constructedwetland with common reed, Manna Grass, and Virginia Mallow,” *Water (Switzerland)*, vol. 10, no. 10, 2018.

[4] K. Kurek, P. Bugajski, A. Operacz, D. Mlynski, and A. Walega, “Technological reliability of sewage treatment plant with the Pomiltek Mann type bioreactor,” *Journal of Water and Land Development*, vol. 46, pp. 146–152, 2020.

[5] A. Micek, K. Jóźwiakowski, M. Marzec, and A. Listosz, “Technological reliability and efficiency of wastewater treatment in two hybrid constructed wetlands in the roztocze national park (Poland),” *Water (Switzerland)*, vol. 12, no. 12, pp. 1–21, Dec. 2020, doi: 10.3390/w12123435.

[6] H. Algretawee, R. J. Mohammad, and M. H. Jassim, “Physical Evaluation for the Raw Water of Tigris River in Baghdad City,” 2013. https://www.researchgate.net/publication/329643062.

[7] M. B. F. and A.-N. B. A. B. Al-Obaidi, “Turbidity and its removal efficiency in the main water purification plants in Nineveh [Online]. Available: overnorate,” *Mesopotamia Journal*, vol. 24, no. 3, pp. 39–53, 2013.

[8] The Central Agency for Standardization and Quality Control, “Iraqi Standard Specifications for Drinking Water,” 2001 [Online]. Available: https://www.cosqc.gov.iq/

[9] A. Y. A. Q. M. A. H. A.-T. M. I. K. Al-Safawi, “Assessment of drinking water quality at the University of Mosul using the WQI Water Quality Index,” *Journal Scientific Studies*, vol. 13, no. 2, pp. 185–198, 2018.

[10] M. S. Khdair and E. Hazim, “Comparison of Some Methods for Estimating the Survival Function and Failure Rate for the Exponentiated Expanded Power Function Distribution,” 2022. [Online]. Available: http://jeasiq.uobaghdad.edu.iq

[11] R. Sharhan and Rahi Abd Alraheem Ggalf, “Estimation of Weibull distribution parameters using the ordinary least squares method and Weighted least-squares method (comparative study),” *Journal of Administration and Economics*, vol. 2, no. 122, pp. 499–506, 2019.

[12] S. S. H. Ald. E. A. F. al-aameri, “Comparing Some Methods of Estimating the Parameters and Survival Function of a Log-logistic Distribution with a Practical Application,” 2022. [Online]. Available: http://jeasiq.uobaghdad.edu.iq.

[13] A. T. R. S. Munfi. Abdel Hadi, “Estimate The Survival Function By Using The Genetic Algorithm,” *Journal of Economics and Administrative Sciences*, vol. 26, no. 122, pp. 440–454, 2020.

[14] K. Jóźwiakowska and M. Marzec, “Efficiency and reliability of sewage purification in long-term exploitation of the municipal wastewater treatment plant with activated sludge and hydroponic system,” *Archives of Environmental Protection*, vol. 46, no. 3, pp. 30–41, 2020.

[15] D. Młyński, A. Młyńska, K. Chmielowski, and J. Pawełek, “Investigation of the wastewater treatment plant processes efficiency using statistical tools,” *Sustainability (Switzerland)*, vol. 12, no. 24, pp. 1–16, 2020.