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Using the Weibull Distribution to Analyze the Reliability of Water Turbidity Removal and the Amount of Chlorine Remaining in the Water After Treatment

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Abstract:

All water treatment centers in Iraq operate according to the standards specified in the legal regulations. Therefore, periodic evaluations must be conducted to study and analyze the quality of the outputs of these centers. The research used the two-parameter Weibull distribution to evaluate the reliability of turbidity removal and residual chlorine in the water at the Rashidiya water center in Baghdad, Iraq. The distribution parameters were estimated using the Maximum Likelihood method with the Matlab 2022 program, and the chi-square test for Goodness of Fit was used at a significant level of 0.05. The study found that the mean (and median = 9 NTU) of turbidity values were 9.47 NTU, which is within the permissible limit, and the mean (and median = 0.03 mg/L) of chlorine values were 0.0295 mg/L, much less than the permissible limit. The study also found that the average efficiency of turbidity removal was 72.179%, which is relatively acceptable, but needs improvement. The analysis showed that the value of reliability for the removal of turbidity was 0.99 ,and for the remaining amount of chlorine was 0.99, indicating that the Rashidiya water center was reliable during the study period. The study recommended several recommendations, the most important of which is the evaluation of all water treatment standards in the Rashidiya water center in particular and in all water treatment centers in Baghdad in general. Maintain continuous turbidity and chlorine levels monitoring to ensure compliance with permissible limits. Make efforts to improve the turbidity removal efficiency. Fostering collaboration between water treatment centers, researchers and regulatory agencies. Develop public awareness campaigns to educate the public on the importance of clean and safe water.

Paper type: Research paper.

Keywords: Efficiency, Reliability, Weibull Distribution, Maximum Likelihood, Water Treatment Center, The Exceedance rate, Chi-square test.

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1. Introduction:

Water treatment center's in many communities need more reliability in treatment processes, which leads to poor quality of treated water and its impact on public health. The reliability of the water treatment process is affected by many factors, including the quality and quantity of treated water, weather conditions and pollution factors. Also, some centre's do not deal with all water pollutants for technical reasons. The importance of measuring all pollutant levels and evaluating their reliability should be noted. Therefore, the main objective is to analyse the reliability of the water treatment process in the centre's by studying several important pollution indicators that these centre's record daily as measurements of these indicators. Statistical analysis techniques will be used to estimate the stations' reliability and identify the factors that affect them.

Water treatment plants are important in providing safe and clean water to communities. One of the most important measures of a water treatment plant's performance is its reliability, which is defined as the probability that the plant will meet the maximum allowable limits of treatment standards within a specified period (Oliveira and Sperling ., 2008)(Bugajski and Nowobilska-Majewska ., 2019). The center fails in the treatment process when the legally defined standards and goals are exceeded (Oliveira and Sperling, 2008) (Marzec et al., 2018). The Tigris River Water Treatment Center in Rashidiya - Baghdad is no exception, and its reliability is essential to ensuring that the water supplied to communities is safe and clean. However, several factors can affect the reliability of the water treatment process, including differences in water quantity and quality, adverse weather conditions, and illegal sewage discharges. (Bugajski and Nowobilska-Majewska , 2019)

In this research, we aim to assess the reliability of the Tigris River water treatment center in Al-Rashidiyah - Baghdad by analyzing turbidity and residual chlorine in the treated water. For reliability estimation, we suggest using the Weibull distribution, which is a general probability distribution widely used in reliability and risk assessment(Micek et al, 2020)(Kurek et al, 2020). We will use the maximum likelihood method, which is accurate and gives better results.

Al-Rashidiyah Water Center is located north of Baghdad, and it is a water treatment plant with a design capacity of 2000 m3/h (Algretawee et al, 2013). The factory adopts a traditional treatment system, which involves drawing raw water from the Tigris River and mixing it with alum in relatively large vats. The water is then distributed over sedimentation ponds and then transferred to filter ponds, where each basin consists of multiple layers of gravel and sand of varying thickness, with a depth of 12 to 14 meters, a length of 4 meters, and a width of 5 meters. Finally, the water is forced into underground tanks for the final chlorination process (Al-Obaidi , 2013).

The reliability of the water treatment process is critical, as any failure to meet treatment standards can lead to serious health consequences for the community. Therefore, our research aims to provide insights into the Tigris River Water Treatment Centre's reliability and identify any operational deficiencies that need to be addressed. By doing so, we hope aim to improve the quality of water that is provided to the communities in Al Rashidiya - Baghdad.

2. Material and Methods:

2.1 Analytical and Statistical:

The current study was conducted for two years (2021-2022), starting from Mar 24th, 2021, until June 16th, 2022. The study relied on daily data collected using modern devices to measure turbidity and chlorine parameters. Turbidity was measured both before and after the treatment process, but the study only relied on the turbidity data obtained after the treatment. On the other hand, chlorine was measured after the treatment process to determine the residual amount of it in the treated drinking water, as it is utilized in the sterilization process.

After treatment, the acceptable limits for discharged water were set at **15** NTU for turbidity and **3** mg/L for residual chlorine (The Central Agency for Standardization and Quality Control, 2001)(Al-Safawi , 2018).

(2.2) Reliability and Efficiency:

The reliability and efficiency of the Al Rashidiya water center were evaluated using the Weibull distribution, which is a statistical method that can be used to model the distribution of failure rates over time. In the case of water treatment plants, the failure rate(Sajit Khdair and Hazim, 2022) is known as the Exceedance Rate(Bugajski and Nowobilska-Majewska , 2019), which represents the proportion of time that the plant exceeds a specified threshold for turbidity or residual chlorine levels.

The Weibull distribution is characterized by a probability density function:(Alwan and Fadel , 2018)

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

The Weibull distribution is characterized by two parameters: the scale parameter (γ) and the shape parameter (τ). These parameters can be estimated using the Maximum Likelihood Estimation (MLE) method, which involves finding the values of γ and τ that maximize the likelihood of the observed data.(Micek et al, 2020)(Bugajski and Nowobilska-Majewska , 2019)

The reliability function of the Weibull distribution is given by the following formula: (al-aameri, 2022)

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

where u is the turbidity or (chlorine) data, and γ and τ are the scale and shape parameters, respectively. The reliability function represents the probability that a Center will operate without exceeding the permissible limit for a given period.(Bugajski and Nowobilska - Majewska, 2019)

The parameters of the Weibull distribution were estimated using the maximum likelihood estimation (MLE) method (Al-Jassim and Abdul, 2013), and the fit of the Weibull distribution to the experimental data was tested using the chi-square test in Matlab 2022 software.

The Maximum Likelihood Estimation method is a common and effective method for estimating probabilistic models, which is based on determining the most likely value of unknown parameters in the model. It is calculated according to the following: (Makowska et al, 2021)

If we assume a random sample of size (m) drawn from a population that has a probability density function $f(u, \gamma, \tau)$, then (Al-Jassim and Abdul , 2013)(Hadia and Redha , 2020):

$$L = \prod_{j=1}^{m} f(u; \gamma, \tau) \qquad (3)$$

Where L is a joint probability density function, therefore the above formula would be written as follows:

$$L(u_1, \ldots, u_m; \gamma, \tau) = \prod_{j=1}^{m} \frac{\tau}{\gamma^{\tau}} u^{\tau-1} exp\left[-\left(\frac{u}{\gamma}\right)^{\tau}\right] \qquad (4)$$

By entering the natural logarithm of the above equation, differentiating it relative to the two parameters of the distribution and then setting it equal to zero, we get:

$$\frac{\partial lnL}{\partial \gamma} = \frac{m}{\tau} + \sum_{j=1}^{m} \ln(u_j) - \frac{1}{\gamma} \sum_{j=1}^{m} (u_j)^{\tau} \ln(u_j) = 0 \qquad (5)$$

$$\frac{\partial lnL}{\partial \tau} = -\frac{m}{\gamma} + \frac{1}{\gamma^2}\sum_{j=1}^{m}(u_j)^{\tau} = 0 \qquad (6)$$

By simplifying equation (5), we get an estimate for $\hat{\gamma}$:

$$\hat{\gamma}_{MLE} = \frac{\sum_{j=1}^{m}(u_i)^{\hat{\tau}_{MLE}}}{m} \qquad (7)$$

And when we substitute equation (7) into (5), we get:

$$\frac{\sum_{j=1}^{m}(u_j{}^{\tau} lnu_j)}{\sum_{j=1}^{m} u_j^{\tau}} - \frac{1}{\tau} - \frac{1}{m}\sum_{j=1}^{m} lnu_i = 0 \qquad (8)$$

The estimator of the shape parameter $\hat{\tau}_{MLE}$ can be obtained by solving the above equation by the numerical methods that are used in solving nonlinear mathematical equations (such as the Newton-Raphson method), from which the reliability function estimator will be as follows:

$$\hat{R}(u)_{MLE} = exp\left[-\left(\frac{u}{\hat{\gamma}_{MLE}}\right)^{\hat{\tau}_{MLE}}\right] \qquad (9)$$

Based on the study data, the following descriptive statistics were computed: mean, median, maximum and minimum values, and standard deviation (Jóźwiakowska and Marzec , 2020) (Młyński et al, 2020).

Turbidity removal efficiency is a measure of the ability of a water treatment process to remove turbidity from it. Turbidity removal efficiency can be calculated by calculating the percentage reduction in turbidity values between the incoming water and the treated water. It was determined using the following formula (Marzec et al, 2018):

$$EFF = \left(1 - \frac{Turbidity_{after}}{Turbidity_{before}}\right) * 100 \qquad (10)$$

whereas:

$Turbidity_{before}$: raw turbidity (the incoming water).

$Turbidity_{after}$: turbidity treatment (the treated water).

3. Discussion of Results:

Descriptive statistics were used to analyze the levels of turbidity and chlorine in the treated water of the Tigris River. The results indicated that the values of both turbidity and chlorine were generally close to the mean and median and met the acceptable standards according to the requirements (The Central Agency for Standardization and Quality Control , 2001). However, in some rare cases, the turbidity values exceeded the required standards, especially during periods of rainfall and torrential rains which could change the water's composition. For instance, the highest recorded turbidity value (59) on December 24, 2021 was above the allowable value. Table (1) summarizes 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	9.47	9	7	59	3.3328
Chlorine	Mg/L	0.0295	0.03	0.02	0.035	0.002047

The reliability of the Rashidiya water center in terms of turbidity and chlorine was assessed using the Weibull distribution. The goodness of fit of the distribution was evaluated by performing a chi-square test with a significance level of 0.05. The estimated parameters of the distribution and the results of the chi-square test are presented in Table 2.

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Table (2) presents the estimated coefficients of the Weibull distribution using the method of The Maximum Likelihood, along with the results of the chi-square test for the experimental data.

Parameter	Unit	Parameter Distribution		chi-square test	
		α	β	Test value	P
Turbidity	Unity	9. 4851	3. 1254	12.5802	0.0830
Chlorine	Mg/L	0.0296	20.0395	7.9554	0.0932

The second table (Table 2) displays the measurement and shape parameters of the Weibull distribution, which were calculated through the method of The Maximum Likelihood, along with the results of the chi-square test for the experimental data.

As shown in Figure 1, the reliability of achieving the required criterion for turbidity (15 units) was 0.99, with exceedance probability (0.1). This indicates that over the 450-day study period, a value equal to or less than 15 units was recorded approximately 450 times.

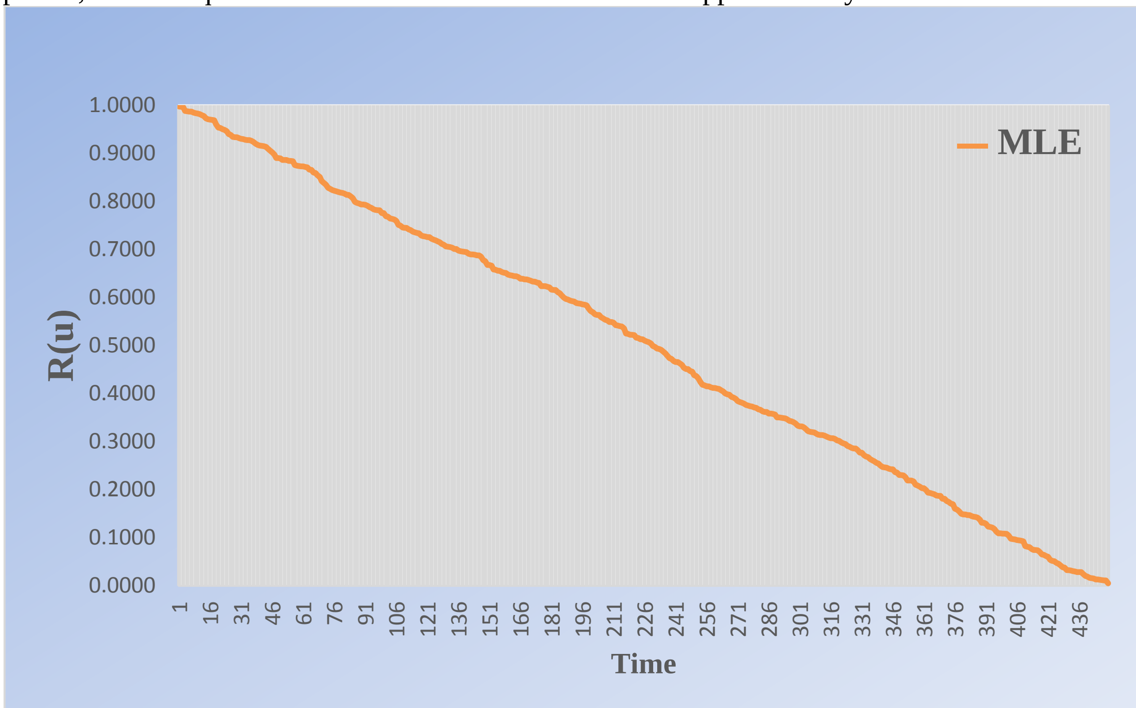

Figure 1: Turbidity reliability estimated using the MLE method.

The reliability of estimates for the turbidity values using the Maximum Likelihood method are shown in Figure (1). The maximum reliability value was (0.99) at the lowest turbidity value, and the lowest reliability value was (0.0024) at the highest turbidity value, demonstrating that reliability values decline as turbidity values rise. Table (3) shows the values of the reliability function for turbidity removal.

Table (3) Reliability function values for turbidity removal.

t	$\hat{R}(u)$	t	$\hat{R}(u)$	t	$\hat{R}(u)$	t	$\hat{R}(u)$	t	$\hat{R}(u)$	t	$\hat{R}(u)$	t	$\hat{R}(u)$
1.	0.9977	65.	0.8728	129.	0.6979	193.	0.5427	257.	0.4192	321.	0.2670	385.	0.1447
2.	0.9974	66.	0.8694	130.	0.6967	194.	0.5399	258.	0.4154	322.	0.2657	386.	0.1423
3.	0.9972	67.	0.8684	131.	0.6964	195.	0.5390	259.	0.4153	323.	0.2644	387.	0.1420
4.	0.9966	68.	0.8674	132.	0.6950	196.	0.5384	260.	0.4131	324.	0.2642	388.	0.1405
5.	0.9937	69.	0.8661	133.	0.6916	197.	0.5367	261.	0.4106	325.	0.2641	389.	0.1386
6.	0.9908	70.	0.8657	134.	0.6830	198.	0.5359	262.	0.4104	326.	0.2616	390.	0.1334
7.	0.9871	71.	0.8619	135.	0.6828	199.	0.5358	263.	0.4100	327.	0.2591	391.	0.1331
8.	0.9847	72.	0.8619	136.	0.6813	200.	0.5348	264.	0.4091	328.	0.2590	392.	0.1325
9.	0.9836	73.	0.8510	137.	0.6799	201.	0.5340	265.	0.4083	329.	0.2563	393.	0.1319
10.	0.9824	74.	0.8451	138.	0.6792	202.	0.5326	266.	0.4057	330.	0.2558	394.	0.1278
11.	0.9819	75.	0.8383	139.	0.6764	203.	0.5303	267.	0.4049	331.	0.2473	395.	0.1237
12.	0.9802	76.	0.8260	140.	0.6741	204.	0.5303	268.	0.4044	332.	0.2466	396.	0.1222
13.	0.9793	77.	0.8254	141.	0.6726	205.	0.5300	269.	0.4025	333.	0.2458	397.	0.1214
14.	0.9785	78.	0.8237	142.	0.6677	206.	0.5292	270.	0.4023	334.	0.2447	398.	0.1205
15.	0.9769	79.	0.8236	143.	0.6666	207.	0.5270	271.	0.4022	335.	0.2444	399.	0.1197
16.	0.9730	80.	0.8210	144.	0.6612	208.	0.5267	272.	0.3972	336.	0.2443	400.	0.1176
17.	0.9713	81.	0.8202	145.	0.6608	209.	0.5216	273.	0.3950	337.	0.2436	401.	0.1170
18.	0.9681	82.	0.8199	146.	0.6584	210.	0.5215	274.	0.3943	338.	0.2408	402.	0.1134
19.	0.9679	83.	0.8179	147.	0.6582	211.	0.5135	275.	0.3913	339.	0.2391	403.	0.1120
20.	0.9658	84.	0.8109	148.	0.6580	212.	0.5080	276.	0.3908	340.	0.2352	404.	0.1096
21.	0.9644	85.	0.8087	149.	0.6577	213.	0.4990	277.	0.3843	341.	0.2350	405.	0.1084
22.	0.9638	86.	0.8080	150.	0.6572	214.	0.4985	278.	0.3788	342.	0.2342	406.	0.1079
23.	0.9616	87.	0.7994	151.	0.6516	215.	0.4965	279.	0.3779	343.	0.2319	407.	0.1017
24.	0.9606	88.	0.7976	152.	0.6463	216.	0.4954	280.	0.3762	344.	0.2299	408.	0.1005
25.	0.9580	89.	0.7925	153.	0.6455	217.	0.4934	281.	0.3743	345.	0.2281	409.	0.0971
26.	0.9558	90.	0.7915	154.	0.6442	218.	0.4927	282.	0.3738	346.	0.2248	410.	0.0967
27.	0.9554	91.	0.7897	155.	0.6415	219.	0.4913	283.	0.3590	347.	0.2245	411.	0.0942
28.	0.9554	92.	0.7841	156.	0.6377	220.	0.4901	284.	0.3574	348.	0.2234	412.	0.0940
29.	0.9553	93.	0.7804	157.	0.6372	221.	0.4899	285.	0.3540	349.	0.2202	413.	0.0917
30.	0.9529	94.	0.7801	158.	0.6339	222.	0.4864	286.	0.3523	350.	0.2179	414.	0.0913
31.	0.9509	95.	0.7774	159.	0.6329	223.	0.4858	287.	0.3517	351.	0.2173	415.	0.0901
32.	0.9503	96.	0.7757	160.	0.6305	224.	0.4836	288.	0.3516	352.	0.2163	416.	0.0883
33.	0.9478	97.	0.7739	161.	0.6296	225.	0.4791	289.	0.3516	353.	0.2161	417.	0.0872
34.	0.9464	98.	0.7736	162.	0.6282	226.	0.4780	290.	0.3486	354.	0.2097	418.	0.0850
35.	0.9459	99.	0.7718	163.	0.6254	227.	0.4766	291.	0.3440	355.	0.2087	419.	0.0832
36.	0.9417	100.	0.7673	164.	0.6249	228.	0.4757	292.	0.3424	356.	0.2069	420.	0.0820
37.	0.9397	101.	0.7621	165.	0.5987	229.	0.4756	293.	0.3386	357.	0.2052	421.	0.0739
38.	0.9383	102.	0.7621	166.	0.5970	230.	0.4721	294.	0.3339	358.	0.2050	422.	0.0680
39.	0.9367	103.	0.7603	167.	0.5939	231.	0.4698	295.	0.3313	359.	0.2020	423.	0.0660
40.	0.9361	104.	0.7571	168.	0.5923	232.	0.4683	296.	0.3313	360.	0.2016	424.	0.0634
41.	0.9342	105.	0.7556	169.	0.5918	233.	0.4669	297.	0.3310	361.	0.2007	425.	0.0614
42.	0.9342	106.	0.7550	170.	0.5911	234.	0.4636	298.	0.3299	362.	0.1975	426.	0.0591
43.	0.9339	107.	0.7528	171.	0.5902	235.	0.4621	299.	0.3277	363.	0.1970	427.	0.0571

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t	$\hat{R}(u)$	t	$\hat{R}(u)$	t	$\hat{R}(u)$	t	$\hat{R}(u)$	t	$\hat{R}(u)$	t	$\hat{R}(u)$	t	$\hat{R}(u)$
44.	0.9334	108.	0.7519	172.	0.5894	236.	0.4609	300.	0.3249	364.	0.1949	428.	0.0525
45.	0.9305	109.	0.7515	173.	0.5874	237.	0.4597	301.	0.3233	365.	0.1890	429.	0.0492
46.	0.9238	110.	0.7485	174.	0.5855	238.	0.4591	302.	0.3232	366.	0.1835	430.	0.0464
47.	0.9214	111.	0.7456	175.	0.5851	239.	0.4588	303.	0.3219	367.	0.1812	431.	0.0457
48.	0.9211	112.	0.7421	176.	0.5832	240.	0.4576	304.	0.3219	368.	0.1802	432.	0.0447
49.	0.9174	113.	0.7375	177.	0.5828	241.	0.4555	305.	0.3216	369.	0.1790	433.	0.0436
50.	0.9173	114.	0.7356	178.	0.5809	242.	0.4538	306.	0.3212	370.	0.1759	434.	0.0423
51.	0.9125	115.	0.7272	179.	0.5797	243.	0.4537	307.	0.3136	371.	0.1736	435.	0.0422
52.	0.9105	116.	0.7266	180.	0.5795	244.	0.4529	308.	0.3132	372.	0.1733	436.	0.0398
53.	0.9102	117.	0.7230	181.	0.5654	245.	0.4501	309.	0.3128	373.	0.1729	437.	0.0392
54.	0.9091	118.	0.7203	182.	0.5625	246.	0.4494	310.	0.3127	374.	0.1727	438.	0.0331
55.	0.9071	119.	0.7199	183.	0.5610	247.	0.4480	311.	0.3097	375.	0.1670	439.	0.0324
56.	0.9022	120.	0.7175	184.	0.5578	248.	0.4463	312.	0.3078	376.	0.1594	440.	0.0300
57.	0.8998	121.	0.7141	185.	0.5560	249.	0.4446	313.	0.3051	377.	0.1592	441.	0.0272
58.	0.8981	122.	0.7130	186.	0.5538	250.	0.4435	314.	0.3014	378.	0.1562	442.	0.0249
59.	0.8905	123.	0.7122	187.	0.5529	251.	0.4420	315.	0.2951	379.	0.1548	443.	0.0197
60.	0.8846	124.	0.7077	188.	0.5504	252.	0.4411	316.	0.2907	380.	0.1544	444.	0.0190
61.	0.8815	125.	0.7042	189.	0.5488	253.	0.4395	317.	0.2892	381.	0.1533	445.	0.0113
62.	0.8799	126.	0.7038	190.	0.5469	254.	0.4320	318.	0.2839	382.	0.1533	446.	0.0108
63.	0.8798	127.	0.7036	191.	0.5463	255.	0.4311	319.	0.2823	383.	0.1520	447.	0.0082
64.	0.8744	128.	0.7014	192.	0.5461	256.	0.4265	320.	0.2733	384.	0.1450	448.	0.0051
												449.	0.0031
												450.	0.0024

The turbidity data has been plotted on a graph, and it can be seen that most of the data is within the allowable range, while some values are outside it. This is acceptable because the study period was relatively long, and it can be attributed to rain and torrential rains that alter the Tigris River's shape. Figure (2) shows the turbidity data graph.

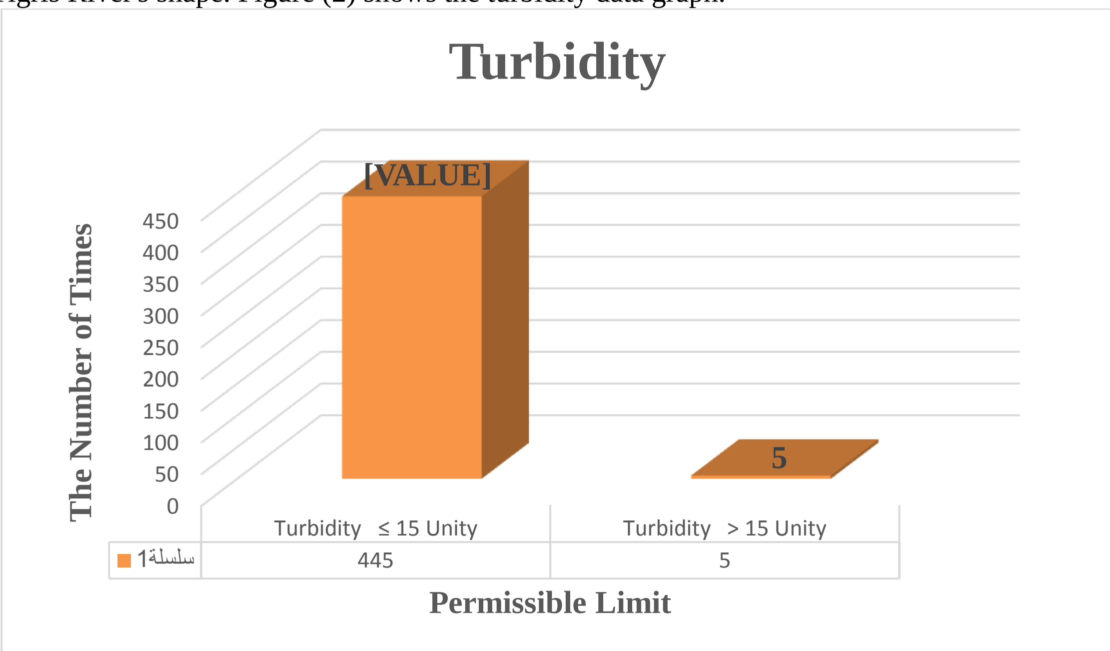

Figure (2) Graph of turbidity data.

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Figure (2) shows a graph of the turbidity values and demonstrates that, while (5) of the total values did exceed the allowable limit for treatment, (445) of the total values did not.

As shown in Figure 3, the reliability of reducing chlorine to the required standards (3 mg/L) was (0.99). With exceedance probability of (0.1). This indicates that over the course of the 450-day study period, a value of (3 mg/L) or greater was not recorded during the study period.

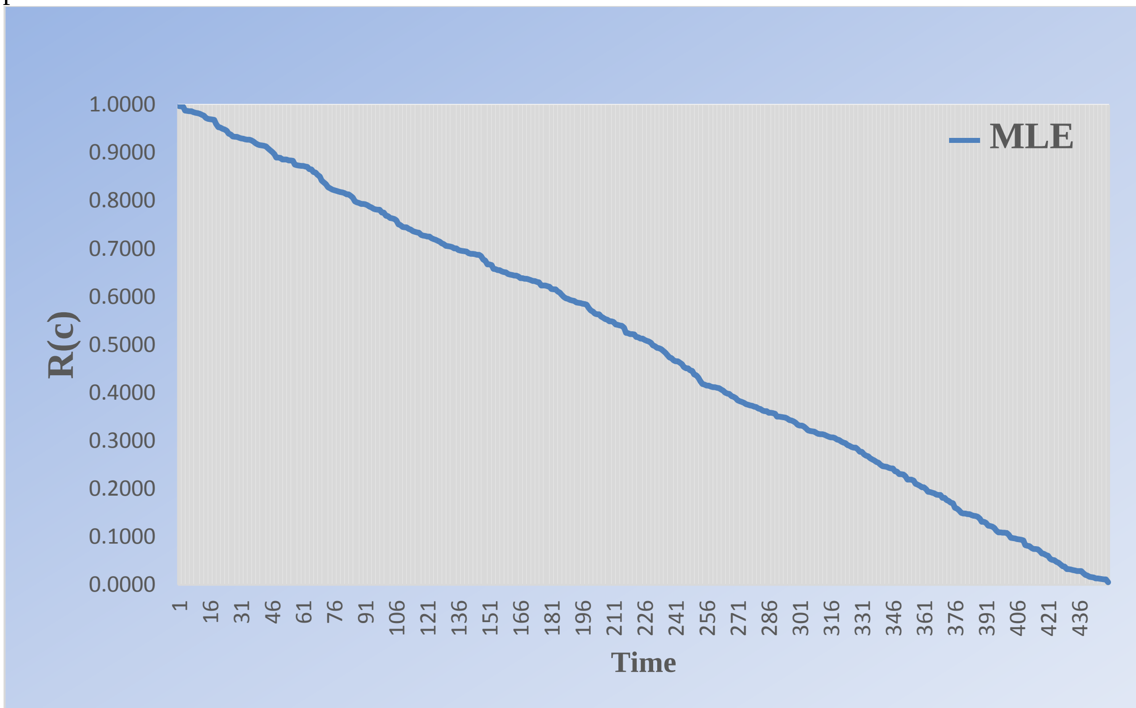

Figure 3: Chlorine reliability estimated using the MLE method.

The Maximum Likelihood method reliability estimates are shown in Figure 3; it appears from the figure that reliability values decline with increasing chlorine values, as the highest reliability value was (0.99) at the lowest chlorine value and the lowest reliability value was (0.0037) at the highest turbidity value. Table (4) shows the values of the reliability function for chlorine.

Table (4) Reliability function values for the amount of residual chlorine.

t	$\hat{R}(c)$	t	$\hat{R}(c)$	t	$\hat{R}(c)$	t	$\hat{R}(c)$	t	$\hat{R}(c)$	t	$\hat{R}(c)$	t	$\hat{R}(c)$
1.	0.9997	65.	0.8450	129.	0.7236	193.	0.5955	257.	0.4422	321.	0.2792	385.	0.1444
2.	0.9920	66.	0.8405	130.	0.7201	194.	0.5908	258.	0.4417	322.	0.2772	386.	0.1388
3.	0.9892	67.	0.8358	131.	0.7146	195.	0.5857	259.	0.4403	323.	0.2766	387.	0.1382
4.	0.9862	68.	0.8352	132.	0.7143	196.	0.5839	260.	0.4392	324.	0.2757	388.	0.1359
5.	0.9785	69.	0.8334	133.	0.7139	197.	0.5804	261.	0.4373	325.	0.2757	389.	0.1299
6.	0.9728	70.	0.8334	134.	0.7120	198.	0.5791	262.	0.4346	326.	0.2752	390.	0.1288
7.	0.9710	71.	0.8306	135.	0.7116	199.	0.5717	263.	0.4346	327.	0.2716	391.	0.1190
8.	0.9710	72.	0.8263	136.	0.7115	200.	0.5710	264.	0.4323	328.	0.2714	392.	0.1184
9.	0.9705	73.	0.8228	137.	0.7114	201.	0.5671	265.	0.4319	329.	0.2673	393.	0.1183
10.	0.9698	74.	0.8215	138.	0.6991	202.	0.5668	266.	0.4308	330.	0.2658	394.	0.1180
11.	0.9686	75.	0.8212	139.	0.6964	203.	0.5664	267.	0.4303	331.	0.2654	395.	0.1177
12.	0.9604	76.	0.8144	140.	0.6961	204.	0.5656	268.	0.4259	332.	0.2643	396.	0.1172
13.	0.9594	77.	0.8102	141.	0.6957	205.	0.5634	269.	0.4257	333.	0.2604	397.	0.1108
14.	0.9570	78.	0.8075	142.	0.6946	206.	0.5597	270.	0.4240	334.	0.2603	398.	0.1098
15.	0.9564	79.	0.8070	143.	0.6931	207.	0.5568	271.	0.4238	335.	0.2501	399.	0.1077

t	$\hat{R}(c)$	t	$\hat{R}(c)$	t	$\hat{R}(c)$	t	$\hat{R}(c)$	t	$\hat{R}(c)$	t	$\hat{R}(c)$	t	$\hat{R}(c)$
16.	0.9557	80.	0.8062	144.	0.6927	208.	0.5501	272.	0.4222	336.	0.2489	400.	0.0993
17.	0.9557	81.	0.8055	145.	0.6914	209.	0.5494	273.	0.4194	337.	0.2485	401.	0.0992
18.	0.9528	82.	0.8045	146.	0.6870	210.	0.5492	274.	0.4134	338.	0.2459	402.	0.0980
19.	0.9515	83.	0.8030	147.	0.6870	211.	0.5490	275.	0.4091	339.	0.2400	403.	0.0974
20.	0.9485	84.	0.8021	148.	0.6818	212.	0.5458	276.	0.4059	340.	0.2373	404.	0.0950
21.	0.9475	85.	0.8003	149.	0.6767	213.	0.5448	277.	0.4057	341.	0.2372	405.	0.0939
22.	0.9455	86.	0.7974	150.	0.6748	214.	0.5444	278.	0.4045	342.	0.2370	406.	0.0880
23.	0.9393	87.	0.7952	151.	0.6732	215.	0.5430	279.	0.4031	343.	0.2358	407.	0.0856
24.	0.9388	88.	0.7950	152.	0.6714	216.	0.5425	280.	0.4000	344.	0.2341	408.	0.0847
25.	0.9388	89.	0.7946	153.	0.6695	217.	0.5415	281.	0.3994	345.	0.2299	409.	0.0828
26.	0.9374	90.	0.7912	154.	0.6686	218.	0.5415	282.	0.3943	346.	0.2210	410.	0.0791
27.	0.9351	91.	0.7858	155.	0.6652	219.	0.5413	283.	0.3935	347.	0.2202	411.	0.0786
28.	0.9344	92.	0.7813	156.	0.6634	220.	0.5410	284.	0.3917	348.	0.2199	412.	0.0780
29.	0.9339	93.	0.7804	157.	0.6625	221.	0.5401	285.	0.3909	349.	0.2198	413.	0.0767
30.	0.9296	94.	0.7768	158.	0.6622	222.	0.5343	286.	0.3873	350.	0.2162	414.	0.0767
31.	0.9289	95.	0.7738	159.	0.6604	223.	0.5272	287.	0.3865	351.	0.2145	415.	0.0745
32.	0.9258	96.	0.7729	160.	0.6571	224.	0.5253	288.	0.3864	352.	0.2143	416.	0.0742
33.	0.9210	97.	0.7720	161.	0.6552	225.	0.5233	289.	0.3836	353.	0.2109	417.	0.0727
34.	0.9197	98.	0.7712	162.	0.6541	226.	0.5219	290.	0.3802	354.	0.2086	418.	0.0708
35.	0.9158	99.	0.7705	163.	0.6491	227.	0.5202	291.	0.3788	355.	0.2083	419.	0.0703
36.	0.9155	100.	0.7665	164.	0.6490	228.	0.5200	292.	0.3741	356.	0.2074	420.	0.0667
37.	0.9096	101.	0.7647	165.	0.6486	229.	0.5176	293.	0.3737	357.	0.2061	421.	0.0634
38.	0.9078	102.	0.7642	166.	0.6473	230.	0.5169	294.	0.3699	358.	0.2038	422.	0.0628
39.	0.9074	103.	0.7638	167.	0.6466	231.	0.5144	295.	0.3684	359.	0.2028	423.	0.0625
40.	0.9054	104.	0.7635	168.	0.6461	232.	0.5141	296.	0.3676	360.	0.2016	424.	0.0573
41.	0.9031	105.	0.7629	169.	0.6393	233.	0.5135	297.	0.3667	361.	0.2008	425.	0.0572
42.	0.9023	106.	0.7592	170.	0.6362	234.	0.5114	298.	0.3661	362.	0.2004	426.	0.0558
43.	0.9001	107.	0.7589	171.	0.6334	235.	0.5076	299.	0.3573	363.	0.1964	427.	0.0504
44.	0.9000	108.	0.7577	172.	0.6325	236.	0.5071	300.	0.3537	364.	0.1960	428.	0.0484
45.	0.8982	109.	0.7574	173.	0.6311	237.	0.5044	301.	0.3529	365.	0.1960	429.	0.0452
46.	0.8979	110.	0.7549	174.	0.6311	238.	0.5031	302.	0.3474	366.	0.1910	430.	0.0378
47.	0.8970	111.	0.7539	175.	0.6269	239.	0.5025	303.	0.3422	367.	0.1902	431.	0.0378
48.	0.8961	112.	0.7535	176.	0.6261	240.	0.5005	304.	0.3399	368.	0.1887	432.	0.0352
49.	0.8934	113.	0.7527	177.	0.6217	241.	0.4985	305.	0.3333	369.	0.1867	433.	0.0337
50.	0.8912	114.	0.7525	178.	0.6195	242.	0.4967	306.	0.3322	370.	0.1855	434.	0.0336
51.	0.8902	115.	0.7503	179.	0.6184	243.	0.4936	307.	0.3253	371.	0.1794	435.	0.0334
52.	0.8857	116.	0.7486	180.	0.6179	244.	0.4903	308.	0.3252	372.	0.1786	436.	0.0199
53.	0.8818	117.	0.7453	181.	0.6177	245.	0.4890	309.	0.3245	373.	0.1781	437.	0.0192
54.	0.8745	118.	0.7444	182.	0.6156	246.	0.4859	310.	0.3187	374.	0.1769	438.	0.0186
55.	0.8738	119.	0.7432	183.	0.6133	247.	0.4775	311.	0.3164	375.	0.1702	439.	0.0185
56.	0.8720	120.	0.7417	184.	0.6128	248.	0.4774	312.	0.3148	376.	0.1635	440.	0.0184
57.	0.8677	121.	0.7417	185.	0.6124	249.	0.4731	313.	0.3132	377.	0.1623	441.	0.0169
58.	0.8674	122.	0.7401	186.	0.6121	250.	0.4704	314.	0.3125	378.	0.1616	442.	0.0133
59.	0.8610	123.	0.7394	187.	0.6108	251.	0.4688	315.	0.3124	379.	0.1597	443.	0.0130
60.	0.8593	124.	0.7327	188.	0.6097	252.	0.4657	316.	0.3048	380.	0.1542	444.	0.0122

t	$\hat{R}(c)$	t	$\hat{R}(c)$	t	$\hat{R}(c)$	t	$\hat{R}(c)$	t	$\hat{R}(c)$	t	$\hat{R}(c)$	t	$\hat{R}(c)$
61.	0.8517	125.	0.7287	189.	0.6022	253.	0.4641	317.	0.2969	381.	0.1511	445.	0.0087
62.	0.8504	126.	0.7267	190.	0.5998	254.	0.4509	318.	0.2966	382.	0.1500	446.	0.0061
63.	0.8479	127.	0.7250	191.	0.5989	255.	0.4441	319.	0.2947	383.	0.1450	447.	0.0059
64.	0.8475	128.	0.7246	192.	0.5979	256.	0.4432	320.	0.2875	384.	0.1446	448.	0.0048
												449.	0.0045
												450.	0.0037

An analysis of chlorine data revealed that none of the levels exceeded the allowed limit of 3 mg/L. A graph of the chlorine data is shown in Figure 4.

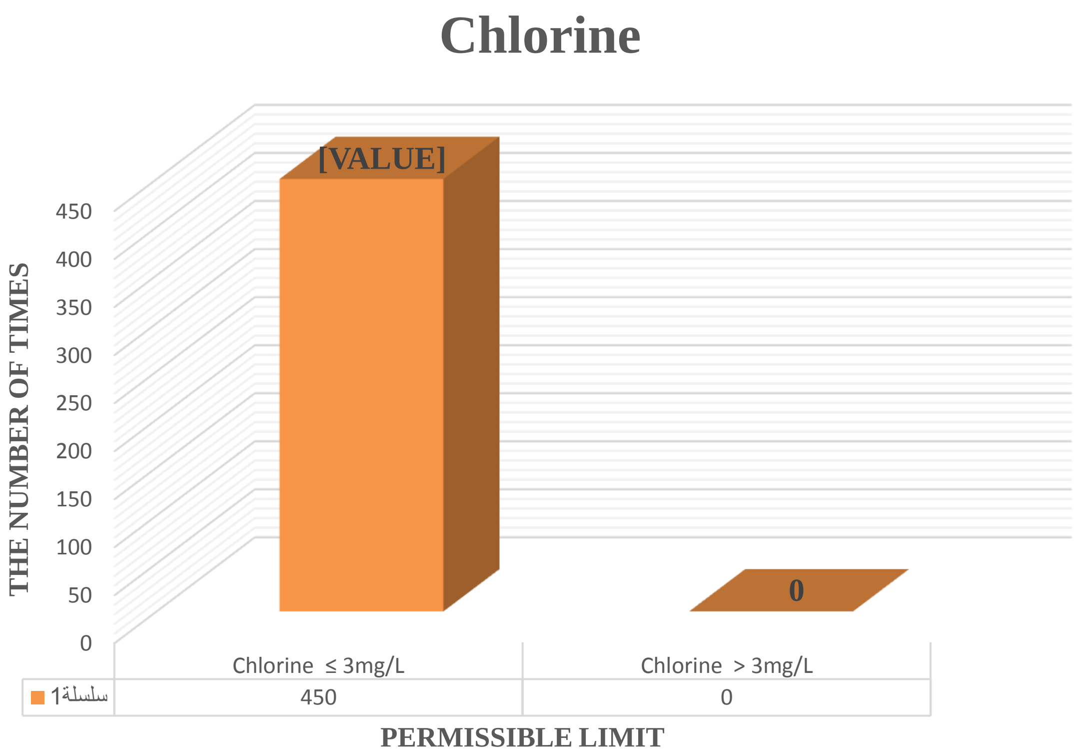

Figure (4) Chlorine data graph.

Since there were no instances of excess during the 450-day research period, Figure (4)'s graph of chlorine readings demonstrates that all values were below the treatment-allowed limit.

4. Conclusion:

The findings of the reliability analysis conducted for the Rashidiya Water Center indicate a high level of reliability for both turbidity and chlorine. The reliability scores obtained were 0.99 for both parameters. This suggests that the water treatment process at the Rashidiya Water Center effectively maintained the desired turbidity and chlorine removal levels. Furthermore, the mean chlorine value was measured at 0.0295 mg/L, with a median of 0.03 mg/L. These values were significantly below the allowable limit, indicating that the water center successfully maintained chlorine levels within the permissible range. Similarly, the mean turbidity value was recorded as 9.47 NTU, with a median of 9 NTU. These measurements were also below the allowable limit, indicating effective turbidity removal during the water treatment process. Based on the treatment criteria, the reliability analysis demonstrates that the Rashidiya Water Center operated within acceptable performance levels during the study period.

The findings support the notion that the center's water treatment processes were reliable and efficient in meeting the required turbidity and chlorine removal standards. These results provide valuable insights into the effectiveness of the water treatment practices at the Rashidiya Water Center. Further scientific discussions can focus on the specific methodologies used in the reliability analysis, the potential factors influencing the observed reliability scores, and any implications these findings may have on the overall water treatment industry. Additionally, suggestions for improving and optimizing the water treatment processes can be explored, based on the achieved levels of reliability and the permissible limits set by regulations.

The study recommends evaluating all water treatment standards in Al Rashidiya water center in particular and in all water treatment centers in Baghdad in general. As some centers measure some water pollutants, and the Rashidiya water center, it measures only the turbidity and the remaining amount of chlorine. It also recommends that the evaluation be carried out in accordance with the unified legal standards stipulated for the treatment of drinking water. In addition, since it is suitable for evaluation, the study proposes to analyze the water treatment parameters using the lognormal distribution. In addition, it is recommended that continuous monitoring of turbidity and chlorine levels be maintained to ensure compliance with permissible limits. Efforts should be made to improve the turbidity removal efficiency. This can be accomplished by investigating factors affecting the process and identifying areas for improvement, such as equipment upgrades or improved filtration methods. Collaboration between water treatment centers, researchers and regulatory agencies should be strengthened. Sharing best practices and research findings can contribute to continuous improvement and adoption of standardized procedures. Public awareness campaigns should be developed to educate the public on the importance of clean and safe water, in addition to the efforts of water treatment centers. This can help raise awareness of the importance of adhering to water quality standards.

Authors Declaration:

Conflicts of Interest: None

-We Hereby Confirm That All The Figures and Tables In The Manuscript Are Mine and Ours. Besides, The Figures and Images, Which are Not Mine, Have Been Permitted Republication and Attached to The Manuscript.

- Ethical Clearance: The Research Was Approved By The Local Ethical Committee in The University.

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استعمال توزيع Weibull لتحليل موثوقية إزالة عكارة المياه وكمية الكلور المتبقية في الماء بعد المعالجة

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مستخلص البحث:
تعمل جميع مراكز معالجة المياه في العراق وفق المعايير المحددة في اللوائح القانونية. لذلك يجب إجراء تقييمات دورية لدراسة وتحليل جودة مخرجات هذه المراكز. هدف البحث إلى تقييم موثوقية إزالة العكارة والكلور المتبقي في المياه في مركز مياه الراشدية في بغداد ، العراق ، باستخدام توزيع ويبل ثنائي المعلمات. تم تقدير معلمات التوزيع باستخدام طريقة الامكان الاعظم بإستخدام برنامج Matlab 2022 ، واستخدم اختبار مربع كاي لملائمة البيانات لتوزيع ويبل عند مستوى معنوي قدره 0.05. وجدت الدراسة أن متوسط قيم التعكر (والوسيط = 9 NTU) كان 9.47 NTU ، وهو ضمن الحد المسموح به ، وكان المتوسط (والوسيط = 0.03 مجم / لتر) لقيم الكلور 0.0295 مجم / لتر وهو أقل بكثير من الحد المسموح به. كما وجدت الدراسة أن متوسط كفاءة إزالة العكارة كان 72.179٪ وهو مقبول نسبيًا ولكنه يحتاج إلى تحسين. أظهر التحليل أن قيمة الموثوقية في إزالة العكارة كانت 0.99 وبالنسبة لكمية الكلور المتبقية كانت 0.99 ، مما يشير إلى أن مركز مياه الراشدية كان موثوقا به خلال فترة الدراسة. أوصت الدراسة بعدة توصيات أهمها تقييم كافة معايير معالجة المياه في مركز مياه الراشدية بشكل خاص وفي كافة مراكز معالجة المياه في بغداد والعراق بشكل عام. كذلك الحفاظ على المراقبة المستمرة لمستويات التعكر والكلور لضمان الامتثال للحدود المسموح بها. وبذل الجهود لتحسين كفاءة إزالة العكارة. وتعزيز التعاون بين مراكز معالجة المياه والباحثين والهيئات التنظيمية. وتطوير حملات توعية عامة لتثقيف الجمهور بأهمية المياه النظيفة والآمنة.

نوع البحث: ورقة بحثية.

المصطلحات الرئيسة للبحث: الكفاءة ، المعولية ، توزيع ويبل ، الامكان الاعظم ، مركز معالجة المياه ، معدل التجاوز ، اختبار مربع كاي.

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