Comparison between the results of applications of the Canadian and Bhargava methods for irrigation water quality index at multi-locations in Tigris River. (A Case Study of Al-amarah Region)

مقارنة بين نتائج تطبيقات الطريقة الكندية وطريقة بهارجافا لمؤشر جودة مياه الري في مواقع متعددة في نهر دجلة. (مدينة العمارة)

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Abstract

To understand the Iraqi water needs for different uses, it is important to study the quality of the water parallel with the quantity. In this research, two national methods are adopted to evaluate and judge the suitability of Tigris River (in Al-amarah region) for irrigation use. These methods include the water quality index (WQI) of the Canadian and Bhargava. These indices have been applied to assess the suitability of water for a variety of uses and reflects the status of water quality in lakes, streams, rivers, and reservoirs. The concept of WQIs is based on a comparison of the concentration of contaminants with the respective environmental standards.
Tigris River is one of the two main rivers passing through Iraqi land, the uses of its water are different and its use for irrigation depends on many environmental parameters (CL^{-1}, Ca^{+2}, Mg^{+2}, TDS, PH, EC, $SO4^{-2}$ and SAR). The researcher studied the quality of this river for irrigation use during year 2011. Seven locations were been taken on the Tigris river in Al-amarah Region in Iraq. The main results showed that there is no difference between the two techniques at significance level (0.01) and the quality of the river inter in Al-amarah Region classified as GOOD and FAIR according to Bhargava and the Canadian method respectively.

الخلاصة

لفهم الاحتياج العراقي للمياه في الاستخدامات المختلفة بشكل جيد، من المهم دراسة نوعية المياه بالتوازي مع الكمية. في هذا البحث، يتم اعتماد طريقتين محليتين للتقييم والحكم على مدى ملاءمة مياه نهر دجلة (مدينة العمارة) لاستخدامها للري. وتشمل هذه الطرق مؤشر نوعية المياه(WQI) من كندا وبهارجافا. وقد طبقت هذه المؤشرات لتقييم مدى ملاءمة المياه لمجموعة متنوعة من الاستخدامات، وتعكس حالة نوعية المياه في البحيرات، والجداول، والأنهار، والخزانات. ويستند مفهوم WQIs على مقارنة تركيز الملوثات مع المعايير البيئية ذات الصلة.
نهر دجلة هو واحد من النهرين الرئيسية التي تمرعبر الأراضي العراقية، واستخدامات مياهه مختلفة واستخدامها لأغراض الري يعتمد على معايير بيئية عديدة (الكلورايد والكلسيوم والمغنيسيوم والأملاح الذائبة الكلية والرقم الهيدروجيني والتوصيل الكهربائي والكبريتات ونسبة امتصاص الصوديوم). درس الباحث نوعية هذا النهر لاستخدامها للري خلال العام 2011 . تم أختيار سبعة مواقع على نهر دجلة في منطقة العمارة في العراق. وأظهرت النتائج الرئيسية أن ليس هناك فرق بين الطريقتين او التقنيتين على مستوى الدلالة (0.01) ونوعية مياه النهر الداخلة في منطقة العمارة تصنف على أنها جيدة وعادلة وفقا لبهارجافا والطريقة الكندية على التوالي.

Introduction

In last years, water resources management, problems, and water quality control received a great deal of researches attention also it is an important environmental protection issue. The rapid growth of agricultural, municipal, and industrial activities especially in heavily populated urban areas and harmful effect of increasing drainage waters coming from agricultural lands upstream coupled with the decreasing in its discharge. It is necessary then to make detailed studies to evaluate the suitability of the two rivers for different uses (Al-Ouebaidy W., 2008).

The case study

The Tigris River in Al-amarah Region was the case study in this study. Seven locations were selected to measure six environmental parameters that affected on the use of the water for irrigation. These locations shown in Figure (1). Table (1) illustrates these locations and their Local names sites.

Table (1) the locations at Tigris River in Al-amarah Region *(2011)*.

No.	No. Location	Location name
1	T29	Ali Al-Garbi
2	T29M	Water project committe
3	T30	Unified water project
4	T30M	River water project
5	T31	Complex water project near the Islamic unity
6	T32	Castle project
7	T33	Uzayr project

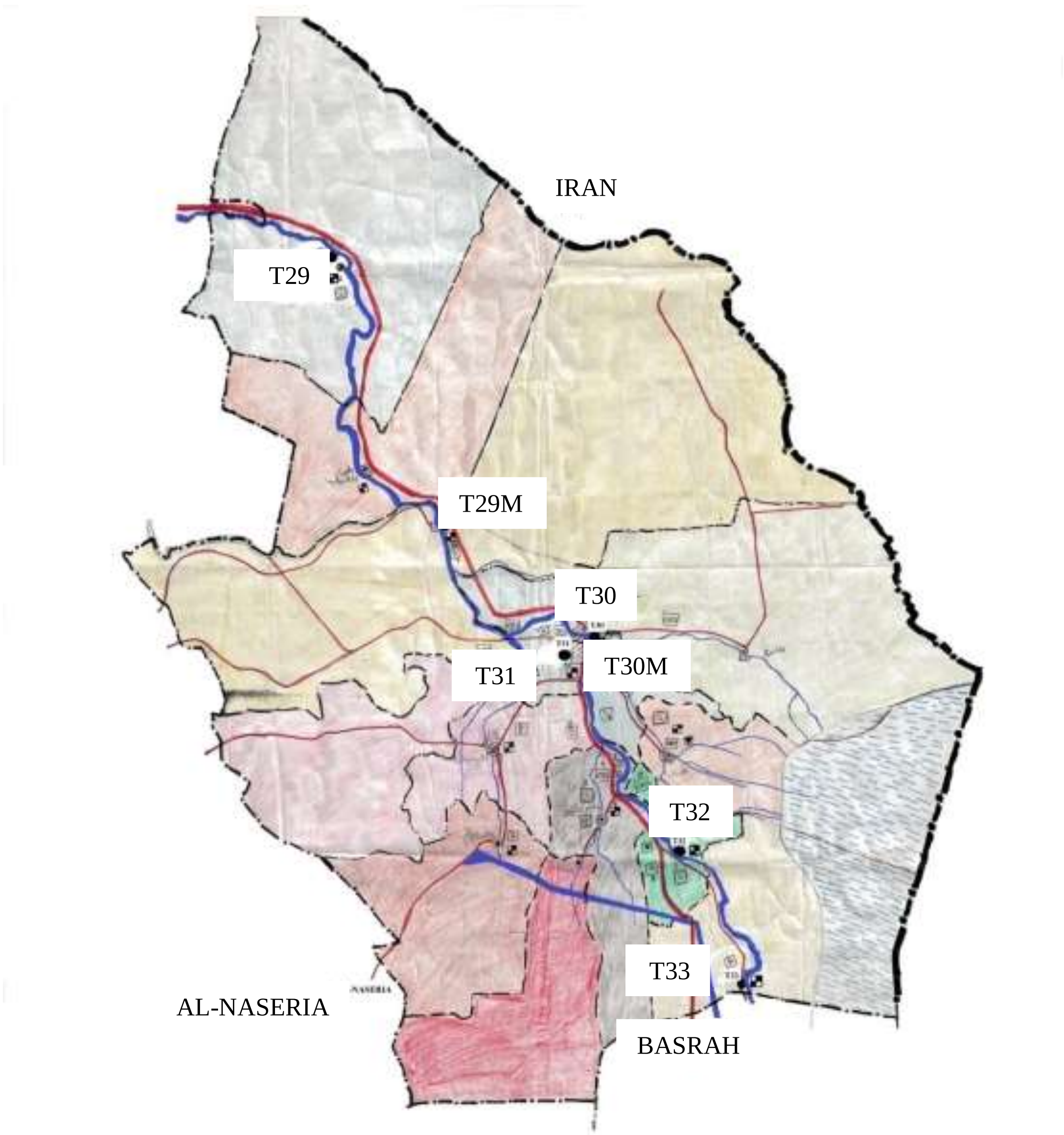

Figure (1) Locations of the case study in the Tigris River at Al-amarah Region in Iraq (Al-amarah Environmental Office, 2011).

Water Quality Index (WQI):

Water quality index (WQI) may have gained currency during the last three decades of the twentieth century, but the concept in its rudimentary form was first introduced more than 150 years ago – in 1848 – in Germany where presence or absence of certain organisms in water was used as indicator of the fitness or otherwise of a water source. WQI was first mentioned by **Horton (1965).** It was considered as an effective tool for collecting various sorts of water quality data to enhance representing them by a principal parameter. This parameter is used to study the changes which result from various polluted water resources. Horton used the water quality index to classify the water and to identify eight physical and chemical determinants to estimate the degradation of water quality. Also, he proposed the rating scales and the weightings for the determinants to give the relative importance for each determinant in the water quality

Considering the simplicity and scientific basis of WQI, it is expected that these indices will provide meaningful summaries of overall water quality and possibly trends. While appreciating the importance and usability of WQIs, it is important to understand the limitations of WQIs. The WQIs are not intended to replace a detailed analysis of environmental monitoring and modeling, nor should they be the sole tool for the management of water bodies. However, WQIs can be used to provide a broad overview of environmental performance that can be conveyed to the public in an easy to understand format. The many advantages of these indices include their ability to represent measurements of a variety of variables in a single number; the ability to combine various measurements with a variety of measurement units in a single metric; and the facilitation of communication of the results. On the other hand, there are limitations in the use of WQIs: the loss of information by combining several variables to a single index value; the sensitivity of the results to the formulation of the index; the loss of information on interactions between variables; and the lack of portability of the index to different ecosystems (Zandbergen and Hall, 1998).

The Canadian Water Quality Index (CWQI)

The Tigris River water quality was compared with WHO/2006 standards Table (2). is classified according to the relative parameters (TDS, pH, Ca^{+2}, Mg^{+2}, EC and $Cl^{=1}$) along the river in Al-amarah region.

The CWQI has adopted the conceptual model of BCWQI (based on relative subindices). There are three factors in the index, each of which has been scaled between 0 and 100. The values of the three measures of variance from selected objectives for water quality are combined to create a vector in an imaginary ‘objective exceedance’ space. The length of the vector is then scaled to range between 0 and 100, and subtracted from 100 to produce an index which is 0 or close to 0 for very poor water quality, and close to 100 for excellent water quality Table (3).

Table (2): Allowable limits of water quality parameters in surface water body used as irrigation water source according to WHO standards
(Abbawi & Mohsen, 1990, WHO,2006).

Parameter	Unit	Irrigation water standards (WHO)
PH		6-8.5
Ec	μs/cm	<250 Excellent 250-750 Good 750-2000 Permissible
Ca^{+2}	mg/L	0-200
Cl^{-1}	mg/L	0-300
Mg^{+2}	mg/L	0-50
TA	mg/L	-
TDS	mg/L	0-700 Excellent 700-2000 Good >2000 Unsuitable
TH	mg/L	-
Tur	NTU	-
SO_4^{-2}	mg/L	-

Table (3) Water quality classification according to CWQI (CCME, 2001)

Class	*Water Quality Index Value*	*Water Quality*
I	100 - 95	Excellent
II	94 - 80	Good
III	79 - 60	Fair
IV	59 - 45	Marginal
V	44 - 0	Poor

Since the index is designed to measure water quality, it was felt that the index should produce higher numbers for better water quality. This earlier version was evaluated on synthetic data sets (Hart, 1998), and data sets from British Columbia (Phippen, 1998) and Newfoundland (Husain, 1998). These evaluations along with evaluations in Alberta and Ontario index revealed that significant problems arose due to the formulations for estimating frequency and amplitude.
The revised CWQI consists of three factors:

Factor 1 (F1): Scope

This factor is called scope because it assesses the extent of water quality guideline non-compliance over the time period of interest. It has been adopted directly from the British Columbia Index:

$$F_1 = \left(\frac{Number\ of\ failed\ variables}{Total\ number\ of\ variables}\right) \times 100, \qquad (1)$$

where **variables** indicate those water quality parameters with objectives which were tested during the time period for the index calculation.

Factor 2 (F2): Frequency

*F*2 (**Frequency**) represents the percentage of individual tests that do not meet the objectives (‘failed tests’):

$$F_2 = \left(\frac{Number\ of\ failed\ tests}{Total\ number\ of\ tests}\right) \times 100, \qquad (2)$$

Factor 3 (F3): Amplitude

*F*3 (**Amplitude**) represents the amount by which the failed test values do not meet their objectives, and is calculated in three steps:

(i) The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an ‘excursion’ and is expressed as follows. When the test value must not exceed the objective:

$$excursion_i = \left(\frac{Failed\ Test\ Value_i}{Objective_j}\right) - 1, \qquad (3)$$

For the cases in which the test value must not fall below the objective:

$$excursion_i = \left(\frac{Objective_j}{Failed\ Test\ Value_i}\right) - 1, \qquad (4)$$

(ii) The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (those which do and do not meet their objectives).

This variable, referred to as the normalized sum of excursions, or *nse*, is calculated as:

$$nse = \frac{\sum_{i=1}^{n} excursion_i}{no.of\ tests} \qquad (5)$$

(iii) *F*3 is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives (*nse*) to yield a range between 0 and 100.

$$F_3 = \left(\frac{nse}{0.01nse + 0.01}\right) \qquad (6)$$

The CWQI is finally calculated as:

$$CWQI = 100 - \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}, \qquad (7)$$

Bhargava Method:

Bhargava Method had been used in many countries , and it is easy to deal with relative parameters for different uses by using sensitivity functions' curves which take value between zero to one. The results were accumulated by using the geometric mean. The sensitivity functions' curves are used to evaluate the quality of river water and give the importance of any parameter for a specific use. It also give weight to every parameter ,for example; when the concentration of sulfate (SO_4^{-2}) get value 400 ppm the sensitivity function will be very low which make water worse according to sensitivity functions' curves for drinking use, while the same concentration value can give sensitivity function equal to 0.8 for irrigation use which mean it is acceptable 80%. The relative parameters for irrigation use are: dissolved solids (TDS), hydrogen number (pH), sulfate (SO_4^{-2}), sodium adsorption ratio (SAR), electrical conductivity (EC), chloride ($Cl^{=1}$). This method was used at Iraq by many researchers such as Al-Safar, 2003 and Al-Ouebaidy, 2009.

The most common water quality factor that influence the normal rate of infiltration of water is the relative concentrations of sodium, magnesium and calcium ions in water that is also known as the sodium adsorption ratio (SAR). The SAR value of irrigation water quantifies the relative proportions of sodium (Na^{+1}) to calcium (Ca^{+2}) and magnesium (Mg^{+2}) and is computed as:

$$SAR = \frac{Na^{+1}}{\sqrt{\frac{Ca^{+2} + Mg^{+2}}{2}}} \qquad (8)$$

In this equation, the concentrations are expressed as milliequivalents per liter. (Ayers & Westcot, 1985).

To characterize the quality of water median,standard deviations as well as maximum and minimum values were calculated for the selected parameters from the data,descriptie statistics for the water quality data of Tigris River in Al-amarah region are given in Table (4).

Table (4) Descriptive statistics for the water quality data of Tigris River in Al-amarah region.

No. Location	parameters	PH	TDS	Cl^{-1}	$SO4^{-2}$	SAR	EC
T29	Max	7.8	1708	500	338	12.5	2530
	Min	7	450	107	200	8.2	1350
	Median	7.2	885	240	259.5	9.6	1622
	Std.Dev.	0.24	333.72	98.78	44.95	1.45	358.34
T29M	Max	7.8	1380	399	294	11.8	2300
	Min	7.3	777	180	200	7.3	1346
	Median	7.4	896	253	245	9.9	1682
	Std.Dev.	0.15	181.41	65.20	23.08	1.81	279.15
T30	Max	8	1400	480	340	12.5	2500
	Min	7.2	788	180	210	6.8	1368
	Median	7.35	915	280	257.5	9.5	1597.5
	Std.Dev.	0.21	193.44	91.91	41.10	1.63	377.10
T30 M	Max	7.9	1460	488	325	13.5	2750
	Min	7.1	833	198	216	7.7	1420
	Median	7.5	906	263.5	264.5	9.68	1588
	Std.Dev.	0.26	196.65	92.65	25.38	1.65	422.17
T31	Max	8	1410	491	330	11.8	2400
	Min	7.3	812	180	60	8.3	1380
	Median	7.35	910.5	257	256.2	9.4	1580
	Std.Dev.	0.21	189.27	95.68	73.16	1.47	342.75
T32	Max	7.9	1390	440	380	13.4	2450
	Min	7.1	784	170	215	8.2	1314
	Median	7.27	973	280	250.7	9.85	1758.2
	Std.Dev.	0.23	176.91	90.38	41.41	1.71	337.89
T33	Max	7.8	1530	440	412	13.3	2960
	Min	7.25	816	190	172.5	8.3	1400
	Median	7.45	992	290	277.5	9.9	1776
	Std.Dev.	0.20	185.05	81.23	63.76	1.62	399.01

This index was used to classify rivers into five groups Table (5) and to determine the water quality index for each activity of different water activities depending upon the variables which affects that activity by using geometric mean formula (Bhargava, 1985).
The geometric mean formula expressed as below:

$$WQI = \left[\pi_{i=1}^{n} \; fi\left(P_i\right)\right]^{1/n} \quad *100 \qquad (9)$$

Where:
f_i (P_i) the sensitivity function for each variable including the effect of variable weight concentration which is related to a certain activity and varies from [0 – 1].

Table (5) Water quality classification according to Bhargava

Class	*Water Quality Index Value*	*Water Quality*
I	100 – 90	Excellent
II	89 – 65	Good
III	64 – 35	Acceptable
IV	34 – 11	Polluted
V	Less than 10	Severe Polluted

Results and Discussion:

The results of the WQIs for Bhargava and the Canadian methods are shown in Table 6 and 7 respectively. It is seen that the WQI for Bhargava method is classified as GOOD for irrigation water use at locations T29 , T29M, T30, T30M while it is classified as ACCEPTABLE at locations T31, T32, T33. The relative parameters for irrigation use are: dissolved solids (TDS), hydrogen number (pH), sulfate (SO_4^{-2}), sodium adsorption ratio (SAR), electrical conductivity (EC), chloride (Cl^{-1}).

Table (6) annual mean for Bhargava WQI.

No. Location	T29	T29M	T30	T30M	T31	T32	T33
BWQI	67	69	66	65	63	62	60
Categorization	Good	Good	Good	Good	Acceptable	Acceptable	Acceptable
Class	II	II	II	II	III	III	III

The Canadian WQI for the irrigation use are classified as GOOD for locations from T29, T29M, while it is classified as FAIR for the locations T30, T31,T32, T30M and it is classified as MARGINAL for the location T33. The researcher used six environmental pollutants which their values were affected in the use of water for irrigation. These parameters are: dissolved solids (TDS), hydrogen number (pH), Calcium (Ca^{+2}), Magnesium(Mg^{+2}), Electrical Conductivity (EC), chloride ($Cl^{=1}$).

Table (7) annual mean for the Canadian WQI

No. Location	T29	T29M	T30	T30M	T31	T32	T33
CWQI	85	87	76	76	79	65	52
Categorization	Good	Good	Fair	Fair	Fair	Fair	Marginal
Class	II	II	III	III	III	III	IV
F1(Scope)	24	20.6	39	40	34	58	80
F2(Frequency)	9.7	8.3	13.8	13.8	12.5	18	20.8
F3(Amplitude)	2.1	1.4	3.1	3.2	3.5	3.6	4.1
CWQI	85	87	76	76	79	65	52

The question is if there is difference between the results of the two methods or not at certain significant limit Figure (2).

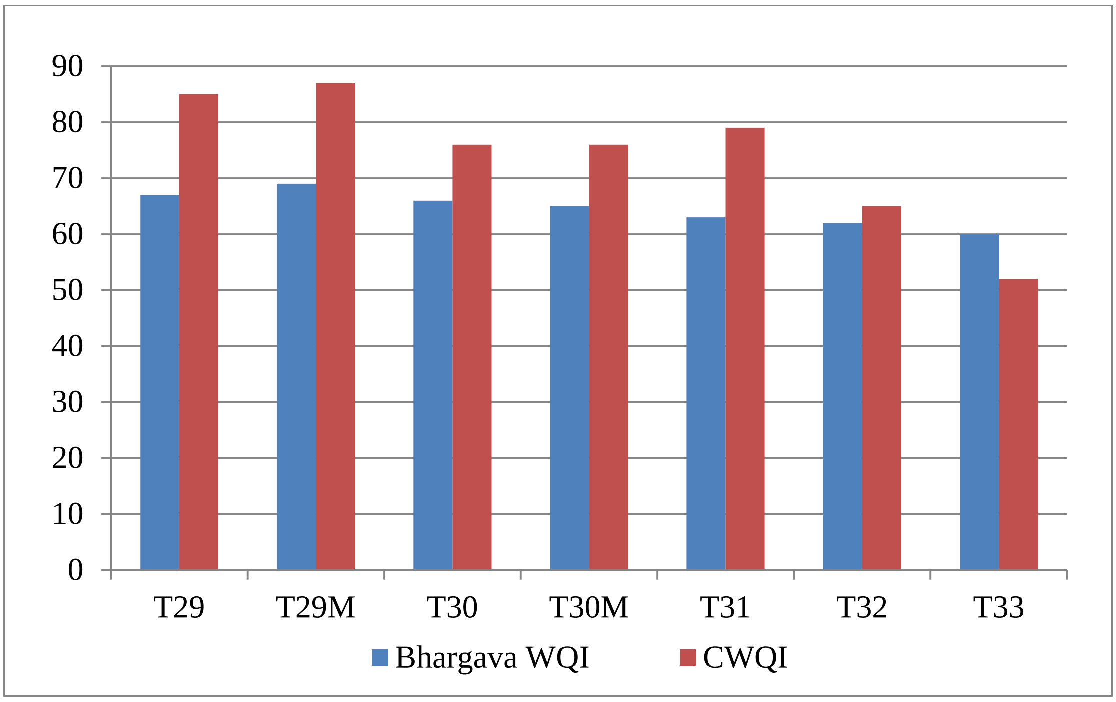

Figure (2) Bhargava and the Canadian WQIs for multi locations at Tigers River in Al-amarah Region

The answer of this question is by using the hypothesis test for arithmetic means of the two method as follows (Abu-Salih and Awad,1990):

1) The null hypothesis: $H_0: \mu_1 = \mu_2$
2) The alternative hypothesis : $H_1: \mu_1 \neq \mu_2$

The statistical decision is accepting the null hypothesis if the absolute value of the test function |T| is less than the tabulated value at t-distribution. The test function is:

$$T = \frac{D}{S_D/\sqrt{N}} \qquad (10)$$

Where:

D : is the arithmetic mean of the difference between the WQI of each location at the two methods, S_D is the standard deviation of the difference, and N is the number of locations

Using equation (10) , it is determined the absolute value of the test function for this problem |T|, which is equal to (2.93). The tabulated value from t-distribution at confidence value equals to 0.99 (1-α/2) and degree of freedom equals to 6 (N-1) is:

t[0.99,6] = 3.143 (from t-table)

The statistical decision is accepted the null hypothesis at significance value (0.02) because the test function |T |= 2.93 is less than the tabulated value t[0.99, 6] = 3.143 (figure 3)

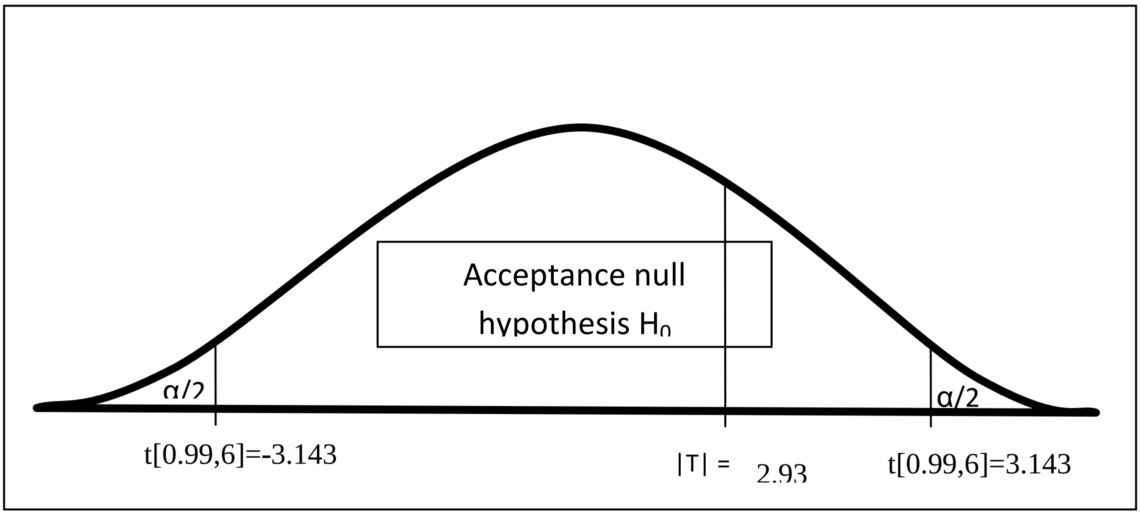

Figure (3): locations of the calculated and tabulated values on the t-curve.

Recommendations:

From the comparison between the results of the two techniques (Bhargava and the Canadian WQIs), it was noticed that there were no significant difference between the results of the two techniques. It is noticed that for Tigris River in Al-amarah Region, the water quality classification according to Bhargava is more appropriate than the water quality classification according to the Canadian method. From this research, it is recommended to use the water quality classification according to Bhargava with the Canadian technique to evaluate the water quality for irrigation and other uses.

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