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ايمان مهدي الموسوي

بإشراف

أ.م.د.

أ.د. رافع هاشم السهيلي  
عبد الحسن الشكر

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# **Multisite Stochastic Model of Water Quality Properties at Selected Regions**

## **A Thesis**

**Submitted to the College of Engineering  
of the University of Babylon in Partial  
Fulfillment of the Requirements  
for the Degree of Master  
of Science in Civil  
Engineering**

**By**

**Eman Mehdi Al-Mousawi**

**Supervised by**

**Prof. Dr.  
Rafa Hashim Al-Suhaili**

**Asst. Prof. Dr.  
Abdul Hassan Al-Shukur**

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TO MY FAMILY

with

LOVE & RESPECT

بِسْمِ اللّٰهِ الرَّحْمٰنِ الرَّحِیْمِ

﴿ وَهُوَ الَّذِي مَرَجَ الْبَحْرَيْنِ هَذَا عَذْبٌ فُرَاتٌ وَهَذَا  
مِلْحٌ أُجَاجٌ وَجَعَلَ بَيْنَهُمَا بَرْزَخًا وَحِجْرًا مَّحْجُورًا ﴾

صدق الله العظيم

سورة الفرقان - الآية ٥٣

# CERTIFICATE

We certify that we have read this thesis, titled “*Multisite Stochastic Model of Water Quality Properties at Selected Regions*”, and as examining committee examined the student “*Eman Mehdi Al-Mousawi*” in its contents and in what is connected with it, and that in our opinion it meets the standard of a thesis for the degree of Master of Science in Civil Engineering.

Signature:

Name: Prof. Dr. Rafa H.Al-Suhaili

(Supervisor)

Date: / /

Signature:

Name: Asst. Prof. Dr. Abdul-Hassan K.Al-Shukur

(Supervisor)

Date: / /

Signature:

Name:

(Member)

Date: / /

Signature:

Name: Asst. Prof. Dr. Jabbar H. Al-Baithani

(Member)

Date: / /

Signature:

Name:

(Chairman)

Date: / /

Approval of the Civil Engineering Department  
Head of the Civil Engineering Department

Signature:

Name:

Date: / /

Approval of the Deanery of the College of Engineering  
Dean of the College of Engineering

Signature:

Name:

Dean of the College of Engineering

University of Babylon

Date: / /

# CERTIFICATION

We certify that this thesis, titled “ *Multisite Stochastic Model of Water Quality Properties at Selected Regions* ”, was prepared by “ *Eman Mehdi Al-Mousawi* ” under our supervision at Babylon University in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering.

Signature:

Name: Prof. Dr. Rafa H.Al-Suhaili  
(Supervisor)

Date: / /

Signature:

Name: Asst. Prof. Dr. Abdul-  
Hassan K.Al-Shukur  
(Supervisor)

Date: / /

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# Chapter One

## Introduction

### 1.1: General :

In recent years water quality problems have attracted increasing attention from authorities and communities throughout the world, especially in developing countries. In these countries previously neglected aspects of environmental protection are now becoming a major obstacle for further and sustainable economic and social development [1].

Most environmental models ignore the fact that natural systems are inherently stochastic, and hence they are of limited value to decision makers, because they attempt to model deterministically processes that are intrinsically combinations of deterministic and stochastic events [2].

The analysis of the existing water quality parameters and the prediction of their concentration changes in future are important in planning of water pollution control program. This analysis and prediction are important steps[3].

Water supplies play an important role in the development of national health and economy. The proper utilization and enjoyment of such supplies depend upon their qualities, which in turn depends on their successful management and proper treatment. This is only possible through the analysis of all available water quality data.

The use of raw water quality data can not be overlooked since such data have considerable effect on the calculation of needed chemical and proper management and treatment and assessing the potentialities of the use of furnished water supplies for different purposes [4].

Stochastic analysis is the useful treatment of data for making quantitative decisions, such as whether water quality is improving or getting worse over time. Another important application of stochastic analysis is the transformation of data to give an understanding of the average and extremes of water quality conditions, and also the changes or trends that may be occurring.

Many mathematical stochastic models are useful tools for water quality management because they enable:

- ١ - Forecasting of impacts of the development of water bodies.
- ٢ - Linking of data on pollution loads with data on water quality.
- ٣ - Provision of information for policy analysis and testing.
- ٤ - Predication of propagation of peaks of pollution of early warning purposes.

Multisite models are widely used in forecasting water quality parameters, flow, rainfall, and other hydrologic phenomena. These models are decomposed the action of many stations and many variables[١٤].

The idea of using a mathematical model to describe the behavior of physical phenomenon is well established. In particular, it is sometimes possible to derive a model based on physical laws, which enable us to calculate the value of some time-dependent parameter nearly exactly at any instant of time. If exact calculations were possible, such a model would be entirely deterministic.

Probably no phenomenon is totally deterministic because of unknown factors that contribute to its variation. So that it is possible to use a deterministic model to describe this phenomenon. Never the less, it may be possible to derive a model that can be used to calculate the probability of a

future value lying between two specified limits, such model is called a stochastic model [٧].

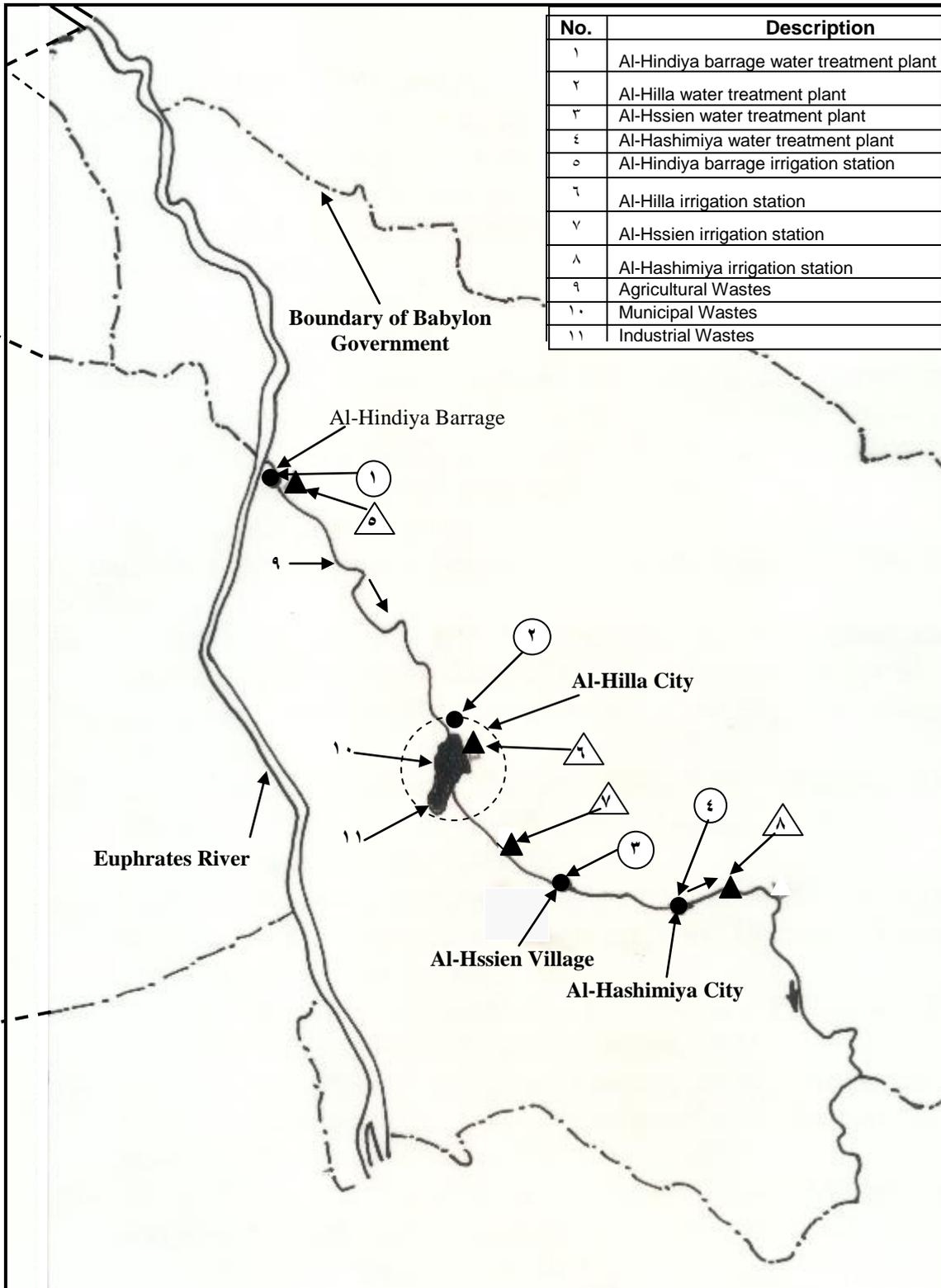
The deterministic part of any phenomenon is represented by the trend and periodic components, where as the non-deterministic part is represented by the stochastic component. The last one contains dependent and independent parts.

The Euphrates river has a large importance in the present time and in the future because of the detrimental effect of pollutants resulting from human activities. Also the harmful effect of the increasing drainage waters coming from agricultural lands upstream coupled with the decreasing in its discharge[٧٧].

Hilla river is a branch of the Euphrates river. It passes through many towns and villages and supplies water to them. The problem of the Hilla river water quality retrogradation is investigated. The decrease in its flow will effect the water quality parameters and frequently result into water quality retrogradation. See Figure (١-١) which represents Al-Hilla river.

In this study, stochastic models is used. These models utilize the time series for the historical data of water quality and discharges of Shutt Al-Hilla at four stations restricted between Al-Hindiya barrage and Al-Hashimiya and estimate their parameters. The river has been subjected to increasing levels of pollution due to the rapid expansion of economic and industrial activities within the river basin. The main source of pollution is of industrial origin but the domestic sector also contributes significantly as there are no major sewage and waste water-treatment plants in the city. A part from the general environmental concern, the water quality levels in the river reach are important to the city water supply engineers as well, because the river water is pumped at several locations for public supplies in the middle Euphrates region. The series of historical data are analyzed. Models are built and used

for both water quality parameters and discharges. The relation between them is investigated now and in future using the predicated data.



**Fig. (١-١) Shutt Al-Hilla and its main of sources of pollutions**

## **1.2: Objective of The Present Study:**

The main objective of the present study is to arrive at a stochastic description of the time series of monthly water quality data consisting of eight Water Quality Parameters (alkalinity, calcium, chloride, electrical conductivity, hardness, magnesium, turbidity and total dissolved solids) with discharges at four stations on Shutt Al-Hilla. This can be achieved by decomposing the data into deterministic and stochastic components and developing suitable mathematical model which adequately describes this process and enable us to forecast the future water quality series required in planning a water pollution control program. The cross-correlation is considered between locations because the stations are expected to be interconnected and related.

# Chapter Three

## Modeling of Water Quality and Discharges Data for The Selected Regions

### ۳.۱: Introduction:

This chapter explains and includes the analysis of the observed historical data of eight water quality parameters and discharges. Measurements of water quality and river discharges were calculated on monthly basis for period (۱۹۸۷-۲۰۰۱) at four stations on Al-Hilla river. Water quality parameters are listed in table (۳-۱).

The analysis of water quality data has become one of the important functions that the environmental engineer must perform. It was complicated by the fact that many of the underlying factors which influence variations in water quality were not well defined. These factors may be further obscured by the occurrence of random events. Consequently the application of statistical techniques to water quality data analysis has become necessary [۱۶].

The overall aim of the analysis is to specify the character of the dependence time series and to find the parameters required to built a stochastic model suitable to generate synthetic water quality data and discharge sequences that are statistically similar to observed data and to show relation between them. Statistical similarity implies generated sequences that have statistics and dependence properties similar to those of historical records[۲۰]. These sets of data are useful in the planning, design and operation of engineering projects, which may reduce the pollutants concentrations in the area. Statistical tests are used to detect trend and jump components (non-homogeneity). A suitable transformation is selected to normalize the data.

**Table (٣-١): List of water quality parameters used for analysis**

Notation	Parameter term	Unit
Alk	Alkalinity	mg/l
Ca	Calcium	mg/l
Cl	Chloride	mg/l
EC	Electrical conductivity	μs/cm
Ha	Hardness	mg/l
Mg	Magnesium	mg/l
TDS	Total dissolved solids	mg/l
Tu	Turbidity	ntu

Auto-correlation analysis is used in the representation and removal of periodic component. Finally standarization is applied to the remaining series which is free from trend and periodic component.

The independent stochastic components are computed for each station by the auto-regressive model AR(١) and tested for independency.

The procedure used for data analysis may be summarized by the following steps:

- ١ - For testing homogeneity, some statistical tests are used to detect if the data series is homogenous or not (which is caused by a trend or a jump component or both).
- ٢ - Removal of non-homogeneity whenever detected by using an appropriate method.
- ٣ - Normalization of data by using a proper transformation such as, logarithmic, square root, or box-cox transformation.
- ٤ - Plotting correlogram for monthly mean and standard deviations of the transformed data to show the effect of periodicity.
- ٥ - Removal of periodicity by applying harmonic analysis which is represented as a fourier series and determination of the number of significant harmonic for monthly means and standard deviations of the series.

- ٦- Standarization of the remaining series.
- ٧- Computation of the serial correlation coefficients ( $r_{\lambda,t}$ ,  $r_{\nu,t}$ ,  $r_{\tau,t}$  and  $r_{\epsilon,t}$ ).
- ٨- Estimation of models parameters.
- ٩- Computing and testing of the independency of the stochastic component.
- ١٠- Calibration of the model if required.
- ١١- Verification of the model.

The steps above may be changed slightly as step (٢) may be applied after step (٧) , however the first approach is better as indicated by Richardson [٥].

After completing of the above steps the stochastic model is ready for data generation.

#### **٣.٢: Filling of Missing Data:**

Data used in the present study consist of monthly means of water quality parameters and discharges at four stations on Al-Hilla river for period (١٩٨٧-٢٠٠١).

The Problem which arises in the use of any statistical analysis is the missing data values [٢١]. These gaps should be filled before starting the data analysis. Among many methods available to obtain a missing value, linear interpolation procedure which is used for filling the gaps to complete the historical record in each station using the software SPSS, (Statistical Package for social sciences). Data from (١٩٨٧) to (١٩٩٨) were used for the analysis and the remaining three years (١٩٩٩-٢٠٠١) were used for model calibration and verification. It's worth to say that the missing data in this research is of small percent (١٥%).

#### **٣.٣: Description of Al-Hilla River and Evaluation of Data Selected for Analysis:**

Al-Hilla river is a branch of the Euphrates river. It branches at Al-Hindiya Barrage town with discharge range (200-270) m<sup>3</sup>/s. The length of Al-Hilla river through Babylon governorate as about (18) Km.

Al-Hilla river passes through many towns and villages and supplies the water for them, thus it represents the main source for different uses such as:

- 1- Irrigation of large agricultural areas on both sides of the river.
- 2- Supply source for many water treatment plants.
- 3- Supply source for industrial plants.

Four main water treatment plants were exist, that draw raw water from the river, Al-Hindiya Barrage, Al-Hilla, Al-Hssien and Al-Hashimiya water treatment plants.

Five types of sources of pollutants [r] were taken into consideration as follows:

- 1 - Treated domestic waste water (municipal and inter-municipal waste water treatment plants (WWTP) as well as septic tank).
- 2 - Untreated waste water (raw waste from sewer networks and directly from house holds).
- 3 - Treated industrial waste water (private and public (WWTP)).
- 4 - Untreated industrial waste water [r] such as textile industry and pepsi cola industry.
- 5 - Farming and agricultural practices.

Other sources of pollution are represented by many drains, which flow into the river and increase the possibility of river pollution.

Source of Al-Hilla river varies during the year according to the information that was supplied by Babylon Irrigation Administration. The main sources of the river water are:

- 1 - Rain water.
- 2 - Stored water such as lakes and reservoirs.

Al-Hilla river, main water supply systems and sources of pollution are presented in Figure (1-1).

Four stations on Al-Hilla river are used for this research and monthly mean values of eight water quality parameters and discharges for period (1987-1998) are used for the basic analysis, the remaining three years (1999-2001) are used for the comparison with the series of data generated using the time series models. In each station data were collected from both raw water (river), and treated water called howafter as water supply.

#### **۲.۴: Test and Removal of Non – homogeneity:**

The need for statistical techniques to test the homogeneity of the water quality parameters considered here in and discharges records was emphasized in section (۲.۱.۲).

The probability of detecting changes in the mean of a sequence  $X_1, X_2, \dots, X_n$  by statistical methods depends on how serious these changes are when only a small change occurs during a short period of the sample record there is little chance that the tests will indicate non-homogeneity. On the other hand, for feasible test-statistics it is necessary that they should be able to indicate all relevant departures from homogeneity [۸].

It is necessary to study the historical data and man-made activities upstream the station before starting this analysis [۴]. Test for homogeneity is made by using the split sample method described in sec. (۲.۲.۴) to ascertain whether or not the differences between the mean and standard deviations of two sub-samples are significantly different from zero at the (۹۷.۵) percent probability level significance. This test requires that the sample is divided into two sub-samples.

The (۱۲) years selected for analysis (1987-1998) are tested for homogeneity using three trials for all water quality parameters and discharges. The first trial is (۴) years long (1987-1990) with (۸) years long (1991-1998), the second trial is (۶) years long (1987-1992) with (۶) years long (1993-1998) and the third trial is (۸) years long (1987-1994) with (۴) years long (1995-1998). The critical (t) value is found as (۲.۲۳) and  $(n_1, n_2)$  are equal (۴, ۸), (۶, ۶) and (۸, ۴) for all parameters

respectively. Test is applied using equations ( $A_1, A_2, A_3$ ) (see–appendix). The critical F–value is different according to the trials. The results are summarized in tables ( $r_1$ ), ( $r_2$ ), ( $r_3$ ) and ( $r_4$ ).







After these attempts of dividing the historical data into two groups of years for each water quality parameters and discharges, it's clear that the high value which gives significant difference in mean or standard deviation was selected. Tables (3-2) to (3-5) indicate that the significant non-homogeneity is due to a jump component because of high discharge especially at (1988).

Figures from (3-1) to (3-4) show annual mean and standard deviation of the original time series for all stations and both raw water and treated water supply. The solid line on these figures represents the average of annual mean and standard deviations of the sub-samples respectively. For the series which show significant difference, the split sample method used for removing the non-homogeneity was explained in section (2.1.4.c). The annual means ( $\bar{X}_j$ ) and annual standard deviations ( $S_j$ ) are fitted by applying equations (3-11) (3-12). The regression coefficients and the overall means and standard deviations of the second sub-samples are calculated also, then the results are summarized in tables (3-6),(3-7),(3-8) and (3-9). The non-homogeneity is removed by applying equations (3-1) for all parameters having the jump component in order to obtain the first new sub-samples, so the new series is free from the jump component for this parameter as show in equation (3-1) for (CA) in Al-Hindiya station, see table (3-6).

$$Y_{j,t} = \frac{X_{j,t} - 175.15 + 7.04j}{17.91 + 0.39j} 31.29 + 88.04 \dots\dots\dots(3-1)$$

After this process, the test of homogeneity is repeated using the new first sub-sample and the original second sub-sample. The results are shown in tables (3-10), (3-11), (3-12) and (3-13) which indicate that the jump component is removed from the data.

Trend component may be detected by means of the significant correlation coefficient [1] using equation (3-2).





















$$t = \frac{r}{\sqrt{(1-r^2)/(n-2)}} \dots\dots\dots (r-2)$$

Where: t : Significant correlation coefficient.  
 r : correlation coefficient of the series.  
 n : Number of years.

If the correlation coefficient of the series is less than the significant correlation coefficient, this means that there is no trend in the series. The results of checking trend are shown in tables (r-14), (r-15), (r-16) and (r-17). The series after check can be considered as homogeneous. Figures (r-5) to (r-8) show and assure the absence of the jump from the series.

**r.5: Transformation to Normally Distribution Data.**

The homogenous series for water quality data and discharges at all stations have significant skewness as shown in table (r-18) and their distribution are far from the normal distribution.

The time series observations of a given phenomenon require a certain type of transformation [10]. It is often better to transform the data to the normal distribution to utilize its simple properties, stabilize the variance, making the seasonal effect additive and improving the normality assumption of the white noise [5].

Several transformations may be used to normalize the data but the most common and the useful class of transforms for stabilizing the variance is known as the Box – Cox transforms [10].

Box and Cox have suggested the following transformation for normality [10].

$$Y = \begin{cases} (X^\lambda - 1)/\lambda & \lambda \neq 0 \\ \log X & \lambda = 0 \end{cases} \dots\dots\dots (r-3)$$

In which Y= Transformed variates.  
 X= Variates of a given series.  
 λ = Constant of transformation.

















Table (3-18): Skewness coefficients of homogeneous data for all stations

Pollutant	Al-Hindiya	Al-Hilla	Al-Hssien	Al-Hashimiya
	C <sub>s</sub>	C <sub>s</sub>	C <sub>s</sub>	C <sub>s</sub>
Alk	-0.162	0.913	0.428	0.023
Ca	-0.373	-0.014	-0.118	-0.366
Cl	-0.004	0.277	-0.103	-0.227
EC	-0.088	-0.060	-0.437	0.208
Ha	-0.201	0.024	-0.052	-0.172
Mg	0.040	-0.067	-0.404	0.344
TDS	0.280	0.992	0.278	-0.189
Tu	0.042	0.324	-0.223	0.040
Q	0.061	0.038	0.482	-0.361

Pollutant	Al-Hindiya	Al-Hilla	Al-Hssien	Al-Hashimiya
	C <sub>s</sub>	C <sub>s</sub>	C <sub>s</sub>	C <sub>s</sub>
Alk	-0.20	0.192	0.491	-0.022
Ca	-0.336	0.121	-0.110	0.109
Cl	-0.010	0.172	0.100	-0.129
EC	0.098	0.000	-0.430	-0.129
Ha	-0.211	0.030	-0.191	-0.276
Mg	-0.040	-0.008	-0.804	-0.036
TDS	-0.487	0.620	0.443	0.091
Tu	-0.097	0.060	0.302	0.480

The value of  $(\lambda)$  generally ranges from  $(-1)$  and  $(1)$ , it is strongly related to the skewness coefficient  $(C_s)$  [9]. The relationship between  $(\lambda)$  and  $(C_s)$  takes the form of second degree polynomial:

$$\lambda = B_0 + B_1 C_s + B_2 C_s^2 + \dots + B_m C_s^m \dots\dots\dots (r-8)$$

Thus, the constant  $(\lambda)$  is nonlinear and can not be determined in the closed form, it can be found by trial and error and choosing random  $(\phi)$  values for  $(\lambda)$  between  $(-1)$  and  $(1)$  and computing the corresponding  $(C_s)$  values for the series after transforming it by equation  $(r-7)$ , then by fitting equation  $(r-8)$  to these  $(\phi)$  points the value of the required  $(\lambda)$  is found as equal to  $(B)$ . The effect of  $(\lambda)$  values on the first four moments (mean, Sd,  $C_s, C_k$ ) is shown in tables  $(r-19)$ ,  $(r-20)$ ,  $(r-21)$  and  $(r-22)$  which also show the values of  $(\lambda)$  that make the skewness coefficient  $(C_s = 0)$ . The normally distributed data has zero skewness and kurtosis equal to  $(3)$ , however, it is found that it is not possible to find  $(\lambda)$  values which simultaneously satisfy the two conditions  $(C_s = 0, C_k = 3)$  of normality.

In order to ensure that the distribution of power transformed data is normal or not, a test of normality was done by plotting  $P(X)$  against  $(X)$  on normal probability paper where:

$$P(X) = \frac{m}{N+1} \dots\dots\dots (r-9)$$

Where  $P(X)$ : Probability of the value  $(x)$ .

$m$ : Rank of  $(X)$  in ascending order.

$N$ : Number of data to be tested.

The resulting plots are the cumulative probability plots which are shown in Figures from  $(r-9)$  to  $(r-12)$  before and after transforming data. The number of data to be tested  $(n)$  for each parameter is equal  $(144)$ . Tables  $(r-23)$ ,  $(r-24)$ ,  $(r-25)$  and  $(r-26)$  show the effect of transformation on the first four moments of each series.

Table(3-19):Effect of ( $\lambda$ ) values on the first four moments of series for Al-Hindiya station

Pollutant	Water type	$\lambda$	Mean	Sd	$C_K$	$C_S$
Alk	Raw water	0.36390	13.0170	0.7089	-0.29	0.0000
Ca		0.00472	19.90417	1.3018	-0.00	0.0000
Cl		1.18430	743.2020	78.0049	-0.74	0.0000
EC		2.11779	1297.7972 1	93823.3 0	-0.09	0.0000
Ha		0.86093	217.8767	12.4290	0.17	0.0000
Mg		1.12191	77.08767	0.4791	1.99	0.0000
TDS		1.23288	28.3882	142.200 2	-0.79	0.0000
Tu		0.70287	9.0370	1.0007	3.00	0.0000
Q		0.87603	119.0170	4.7900	1.98	0.0000

Pollutant	Water type	$\lambda$	Mean	Sd	$C_K$	$C_S$
Alk	Water supply	0.44090	17.4833	0.9242	-0.29	0.0000
Ca		0.44409	13.99767	0.8097	-0.01	0.0000
Cl		0.99200	249.7770	20.8310	-0.77	0.0000
EC		0.33328	27.19	0.4332	-0.79	0.0000
Ha		0.70767	98.09	3.2481	-0.11	0.0000
Mg		0.70477	24.270	1.0291	0.43	0.0000
TDS		0.81881	209.000	9.1938	-0.82	0.0000
Tu		1.10220	0.239177	0.3879	2.74	0.0000

Table(3-20):Effect of ( $\lambda$ ) values on the first four moments of series for Al-Hilla station

Pollutant	Water type	$\lambda$	Mean	Sd	$C_K$	$C_S$
Alk	Raw water	- 0.48000	1.883333	0.00701	0.97	0.0000
Ca		0.70404	27.76833	2.8017	-0.22	0.0000
Cl		1.22942	709.9117	87.2277	-0.99	0.0000
EC		1.90797	32.4778	21737.41	0.03	0.0000
Ha		1.18941	1.9790	94.1374	-0.73	0.0000
Mg		0.83309	27.70	2.0201	1.17	0.0000
TDS		3.74277	13.90079027 0	19.000000 0	-0.01	0.0000
Tu		0.87224	3.8233	0.1880	1.07	0.0000
Q		1.73223	2043.94	279.4331	2.03	0.0000

Pollutant	Water type	$\lambda$	Mean	Sd	$C_K$	$C_S$
Alk	Water supply	0.14722	3.47	0.2392	1.92	0.0000
Ca		0.74304	37.17	3.8110	-0.11	0.0000
Cl		1.04349	303.3000	23.1777	-1.01	0.0000
EC		1.09773	39881.00	200.002	0.23	0.0000

<b>Ha</b>		۱.۲۴۸۵۳	۱۳۳۵.۱۴	۱۲۴.۲۵۸	-۰.۲۹	۰.۰۰۰۰
<b>Mg</b>		۰.۲۷۹۹۵	۲.۳۳	۰.۰۱۸۰۱	۰.۳۸	۰.۰۰۰۰
<b>TDS</b>		۰.۱۳۶۴۷	۴.۳۵	۰.۰۱	۱.۸۶	۰.۰۰۰۰
<b>Tu</b>		۰.۵۵۶۴۵	۳.۶۵	۰.۲۶۵۹	۳.۱۵	۰.۰۰۰۰

Table(3-21):Effect of ( $\lambda$ ) values on the first four moments of series for Al-Hssien station

Pollutant	Water type	$\lambda$	Mean	Sd	$C_K$	$C_S$
Alk	Raw water	-0.44602	1.9933	0.00492 ε	0.08	0.0000
Ca		0.80886	0.9267	0.0406	0.99	0.0000
Cl		0.92440	194.000	14.7989	-0.24	0.0000
EC		1.12818	2077.040	123.003 γ	0.03	0.0000
Ha		0.89984	277.0692	19.6402	0.66	0.0000
Mg		1.14746	80.0608	9.7330	-0.18	0.0000
TDS		0.89099	40.2467	17.7400	3.79	0.0000
Tu		1.11063	43.7770	3.8897	3.00	0.0000
Q		1.30422	091.9117	04.3.70	2.00	0.0000

Pollutant	Water type	$\lambda$	Mean	Sd	$C_K$	$C_S$
Alk	Water supply	-1.16190	0.8600	0.00	-0.36	0.0000
Ca		0.81747	0.7633	0.2737	0.89	0.0000
Cl		0.79206	10.43900	7.7488	-0.48	0.0000
EC		2.07819	108962	93129.8 λ	-0.70	0.0000
Ha		1.17102	110.76133	93.1838	0.31	0.0000
Mg		0.14028	0.617	0.9998	3.26	0.0000
TDS		0.97830	719.91	37.9400	0.40	0.0000
Tu		0.32730	2.9317	0.2630	-0.06	0.0000

Table(3-22):Effect of ( $\lambda$ ) values on the first four moments of series for Al-Hashimiya station

Pollutant	Water type	$\lambda$	Mean	Sd	$C_K$	$C_S$
Alk	Raw water	-0.61892	1.0370	0.00402	1.28	0.0000
Ca		0.91219	7.008	0.8020	0.04	0.0000
Cl		0.07339	41.02	2.8016	1.06	0.0000
EC		2.20400	3348494.7 0	349607.7 γ	0.06	0.0000
Ha		0.98408	40.830	24.0209	-0.30	0.0000
Mg		1.11120	60.28	3.1187	4.19	0.0000
TDS		0.67630	137.68	2.0220	-0.12	0.0000
Tu		0.60718	11.61	0.7001	0.77	0.0000
Q		1.32067	428.87	44.3380	1.27	0.0000

Pollutant	Water type	$\lambda$	Mean	Sd	$C_K$	$C_S$
Alk	Water supply	-0.17684	3.18	0.3600	0.27	0.0000
Ca		0.82028	47.38	4.3106	0.10	0.0000
Cl		1.10688	434.84	27.6779	-0.88	0.0000
EC		1.30034	6906.78	442.728 ε	-0.01	0.0000

<b>Ha</b>		۱.۱۲۶۴۸	۸۲.۲۸	۴۳.۴۹.۶	-۰.۷۰	۰.۰۰۰۰
<b>Mg</b>		۰.۹۴۲۵۸	۳۷.۶۲	۱.۷۲۱۴	۰.۹۱	۰.۰۰۰۰
<b>TDS</b>		۰.۸۳۹۲۵	۳۱۵.۴۵	۱۲.۶۷۵۴	-۰.۰۷	۰.۰۰۰۰
<b>Tu</b>		۱.۰۲۲۴۷	۸.۷۱	۱.۳۳۶۲	-۰.۳۸	۰.۰۰۰۰









**3.1: Detection and Removal of Periodic Component:**

Generally, water quality data series have small periodicity, because the concentration of any parameter changes continuously in the river and do not repeat it self at the same position in the following year [1].

Detection of the periodic component can be made by the construction of the correlogram of the data. If the series is periodic, the correlogram will also be periodic [17], otherwise it is not. The serial correlation coefficients of the normalized data at four stations are calculated using equation (3-22). The correlograms for each parameter after normalization of the data are shown in Figures (3-13), (3-14). The high magnitude of the peak values shows that the deterministic periodic component form a dominant part of monthly time series.

Removal of periodicity from the data is done by harmonic analysis to monthly means and standard deviations using the fourier series. Harmonic analysis is done by using the following steps:

- 1- Calculation of sample monthly means and monthly standard deviations, ( $\bar{X}_t$  and  $S_t$ ) for ( $t = 1, 2, 3, \dots, 12$ ).
- 2- Computation of the fourier coefficients ( $A_j, B_j$ ) using equations (3-18) (3-19).
- 3- Determination of the number of significant harmonics for means and standard deviations using the empirical method with  $n = 12, w = 12, C = 1$  for means and  $C = 2$  for standard deviations.
- 4- Applying equation (3-17) to calculate the periodic component of means ( $\mu_t$ ) and standard deviations ( $\sigma_t$ ).
- 5- Removal of periodic component from data series by:

$$Y_{j,t} = \frac{X_{j,t} - \mu_t}{\sigma_t} \dots\dots\dots (3-21)$$

Where:  $Y_{j,t}$ : Series free from periodic component at year (j) and month (t).

$X_{j,t}$ : Homogenous series.













Then, the result series is further standardized to ascertain a zero mean and a unit variance [ $\sigma_y$ ].

Thus:

$$\varepsilon_{j,t} = \frac{Y_{j,t} - \mu_y}{\sigma_y} \dots\dots\dots(\sigma_y)$$

Where:  $\varepsilon_{j,t}$ : Dependent stochastic component.

$\mu_y$ : Mean of ( $Y_{j,t}$ ) series.

$\sigma_y$ : Standard deviation of ( $Y_{j,t}$ ) series.

By applying the above harmonic analysis steps to homogeneous normalized water quality data series and discharges, it is clear that the harmonics are significant at the six harmonics for all stations as shown in tables from (3-22) to (3-28). This indicates that the estimation of maximum number of harmonics which equals ( $w/\sigma_y$ ) is a good estimation.

Even though using high numbers of harmonics in the parametric method, no good fit is obtained as shown in Figures from (3-15) to (3-18). Hence, the non-parametric method is used here for the removal of the periodic component (as explained in sec. 2.1.5 (a)).

The result series is called stochastic series. It contains a dependency in time which was represented by an [AR(P)] for singlesite models and Matalas method for multisite model, an independent part that can only be described by some probability distribution function can be found.

**2.1: Singlesite Model:**

The selection of the most appropriate model depends on the behavior of the auto-correlation function (ACF) coupled with that of partial auto-correlation function (PACF) of the dependent stochastic component.

























The (ACF) measures the amount of linear dependence between the observations in a time series that are separated by lag (K). The (PACF) is an important tool in determining the order of the model if the serial correlation function suggests that the process could be approximated by linear auto-regressive model [22]. The concept of model parsimony is followed i.e. a model with the smallest possible number of parameters is preferable [18].

Figures (3-19), (3-20) show the (ACF) and (PACF) for the dependent stochastic components of the series at four stations. It is obvious from figures that the process is an auto-regressive one. Since the (ACF) have much more points lying outside the limits than those for the (PACF).

The single site model to fit the  $(\varepsilon_t)$  series is tested, this model is auto-regressive AR(1) (Markov) model. The general form of this linear model is:

$$\varepsilon_{j,t} = \alpha_1 \varepsilon_{j,t-1} + \sigma \xi_{j,t} \dots\dots\dots (3-8)$$

Where:

$\varepsilon_{j,t}$ : Dependent stochastic component at year (j) and month (t).

$\xi_{j,t}$ : Independent stochastic component at year (j) and month (t).

$\alpha$  and  $\sigma$ : Parameters of the model .

$$\alpha_1 = r_1 \dots\dots\dots (3-9)$$

$$\sigma = \sqrt{1 - \alpha_1^2} \dots\dots\dots (3-10)$$

The values of ( $\alpha$  and  $\sigma$ ) for the water quality data and discharges of four stations are shown in tables from (3-23) to (3-26). To test the independency of the resulting  $(\xi_{j,t})$  series, the correlograms of this series are computed up to lag (N/5) [18] shown in Figures (3-21), (3-22). The tolerance limits given by Anderson and computed by Eq. (3-33) are equal to  $(\pm 0.05)$  at the (95.0) percent significant probability level. The results show that the most of computed lags lie inside the tolerance interval, therefore the series can be considered to exhibit a white noise term (independency). Hence the AR(1) model can be considered satisfactory because of its capability of removing the dependency from data.











**3.1: Multisite Auto - Regressive Model:**

Matalas method is used to model multisite problems. This method depends on cross-correlation between stations, besides the serial correlation coefficient, using first order form developed by Matalas as given by equation (3-11).

$$\varepsilon_t = A\varepsilon_{t-1} + B\xi_t \dots\dots\dots(3-11)$$

where (A) and (B) are the coefficients matrices given by equations (3-12), (3-13), respectively.

The parameters of the multisite model are the two matrices (A) and (B). to find these two matrices, the lag-zero (M<sub>0</sub>) and lag-one (M<sub>1</sub>), cross-correlation matrices are calculated by using equation (3-14). Matrix (A) was found directly from equation (3-12) while matrix (B) was found from equation (3-13) based on Young and Pisano method [39]. Tables (3-14), (3-15) show matrices (M<sub>0</sub>, M<sub>1</sub>, A, B) for all water quality parameters and discharge at four stations.

Table (3-47): Matrices for multisites model (M., M<sub>1</sub>, A, B) for all pollutants and discharge at four stations (raw water)

M.

Pollutant	Alk			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	1.000	0.420	0.609	0.469
Hindiya	0.420	1.000	0.300	0.482
Hashimiya	0.609	0.300	1.000	0.508
Hssien	0.469	0.482	0.508	1.000

M<sub>1</sub>

Pollutant	Alk			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	0.606	0.240	0.498	0.438
Hindiya	0.529	0.416	0.468	0.568
Hashimiya	0.508	0.324	0.696	0.490
Hssien	0.400	0.297	0.569	0.717

Matrix A

Pollutant	Alk			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	0.571	-0.116	0.60	0.194
Hindiya	0.272	0.106	0.72	0.303
Hashimiya	0.040	0.022	0.576	0.168
Hssien	-0.073	-0.092	0.331	0.628

Matrix B

Pollutant	Alk			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	0.732	0.000	0.000	0.000
Hindiya	0.030	0.709	0.000	0.000
Hashimiya	0.364	-0.072	0.593	0.000
Hssien	0.130	0.000	-0.014	0.630

Table (٣-٤٧): Continued

M٠

Pollutant	Ca			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	١.٠٠٠	٠.٨٣٣	٠.٧٧٧	٠.٧٦١
Hindiya	٠.٨٣٣	١.٠٠٠	٠.٧٧٤	٠.٦٩٢
Hashimiya	٠.٧٧٧	٠.٧٧٤	١.٠٠٠	٠.٨٠٢
Hssien	٠.٧٦١	٠.٦٩٢	٠.٨٠٢	١.٠٠٠

M١

Pollutant	Ca			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٨٨٣	٠.٧٧٩	٠.٧٦٦	٠.٧٥٥
Hindiya	٠.٧٤١	٠.٨٢٧	٠.٧١٥	٠.٦٧٣
Hashimiya	٠.٧١٤	٠.٧١٦	٠.٨٧٦	٠.٧٤٨
Hssien	٠.٦٩١	٠.٦٥٩	٠.٧٦٢	٠.٨٥٣

Matrix A

Pollutant	Ca			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٦٤٠	٠.٠٧٠	٠.١٠٨	٠.١٣٣
Hindiya	٠.٠٥٢	٠.٦٢٨	٠.٠٨٢	٠.١٣٣
Hashimiya	٠.٠٠٥	٠.٠٧٣	٠.٧٢٦	٠.١١٢
Hssien	-٠.٠٢٥	٠.٠٦٧	٠.١٩١	٠.٦٧٢

Matrix B

Pollutant	Ca			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٤٤٣	٠.٠٠٠	٠.٠٠٠	٠.٠٠٠
Hindiya	٠.٣٠٤	٠.٤٤٨	٠.٠٠٠	٠.٠٠٠
Hashimiya	٠.١٧١	٠.١٤٢	٠.٤١٨	٠.٠٠٠
Hssien	٠.١٧٣	٠.٠٢٩	٠.١٦٢	٠.٤٤٣

Table (٣-٤٧): Continued

M٠

Pollutant	CI			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	١.٠٠٠	٠.٨٥٠	٠.٨٠٣	٠.٧٤٧
Hindiya	٠.٨٥٠	١.٠٠٠	٠.٨٣٨	٠.٧٩٣
Hashimiya	٠.٨٠٣	٠.٨٣٨	١.٠٠٠	٠.٨٠٦
Hssien	٠.٧٤٧	٠.٧٩٣	٠.٨٠٦	١.٠٠٠

M١

Pollutant	CI			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٩٠١	٠.٧٩٩	٠.٧٨٥	٠.٧٤٣
Hindiya	٠.٨١٢	٠.٨٨٢	٠.٨٢١	٠.٧٦٠
Hashimiya	٠.٧٨١	٠.٧٩٥	٠.٩١٩	٠.٧٦٩
Hssien	٠.٧٢٧	٠.٧٢٣	٠.٧٥٤	٠.٨٠٦

Matrix A

Pollutant	CI			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٧٣٣	-٠.٠٠٣	٠.١١٣	٠.١٠٨
Hindiya	٠.١٤٣	٠.٥٤٦	٠.٢٠٣	٠.٠٥٦
Hashimiya	٠.١٠٨	٠.٠٠١	٠.٧٩٢	٠.٠٤٩
Hssien	٠.٢١٠	-٠.٠٢٢	٠.١٩٠	٠.٥١٤

Matrix B

Pollutant	CI			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٤١٧	٠.٠٠٠	٠.٠٠٠	٠.٠٠٠
Hindiya	٠.١٩٨	٠.٣٩٠	٠.٠٠٠	٠.٠٠٠
Hashimiya	٠.١١٠	٠.١٠٢	٠.٣٥٥	٠.٠٠٠
Hssien	٠.١٠٧	٠.١٩٠	٠.١٦٧	٠.٤٧٩

Table (٣-٤٧): Continued

M٠

Pollutant	EC			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	١.٠٠٠	٠.٨٦١	٠.٧١٤	٠.٧٣١
Hindiya	٠.٨٦١	١.٠٠٠	٠.٧٦٦	٠.٧٢٦
Hashimiya	٠.٧١٤	٠.٧٦٦	١.٠٠٠	٠.٦٥٦
Hssien	٠.٧٣١	٠.٧٢٦	٠.٦٥٦	١.٠٠٠

M١

Pollutant	EC			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٨٦٠	٠.٧٤٧	٠.٦١١	٠.٦٤٣
Hindiya	٠.٧٩٧	٠.٨١٥	٠.٦١٧	٠.٦١١
Hashimiya	٠.٦٩١	٠.٧١٦	٠.٧٤٧	٠.٦١١
Hssien	٠.٧٣٣	٠.٧٠٣	٠.٥٥١	٠.٧٩٨

Matrix A

Pollutant	EC			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٨٣١	٠.٠٢٧	-٠.٠٢٤	٠.٠٣١
Hindiya	٠.٣٩٥	٠.٥٤٥	-٠.٠٦٠	-٠.٠٣٤
Hashimiya	٠.١٦٧	٠.١٨٨	٠.٤٤٣	٠.٠٦١
Hssien	٠.٢٨٩	٠.١٥٠	-٠.١٤٨	٠.٥٧٥

Matrix B

Pollutant	EC			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٥٠٨	٠.٠٠٠	٠.٠٠٠	٠.٠٠٠
Hindiya	٠.٣٣٧	٠.٤٢٩	٠.٠٠٠	٠.٠٠٠
Hashimiya	٠.٢٣٣	٠.٢٠٦	٠.٥٣٢	٠.٠٠٠
Hssien	٠.١٧٨	٠.١٢٢	٠.٠٧٦	٠.٥٠٢

Table (٣-٤٧): Continued

M.

Pollutant	Ha			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	١.٠٠٠	٠.٨٦٦	٠.٧٨٥	٠.٦٣٦
Hindiya	٠.٨٦٦	١.٠٠٠	٠.٨٤٤	٠.٦٧٦
Hashimiya	٠.٧٨٥	٠.٨٤٤	١.٠٠٠	٠.٦٣٥
Hssien	٠.٦٣٦	٠.٦٧٦	٠.٦٣٥	١.٠٠٠

M١

Pollutant	Ha			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٨٧٦	٠.٨٠٧	٠.٧٨٦	٠.٦٢٦
Hindiya	٠.٨١٧	٠.٨٩٩	٠.٨٤٣	٠.٦٢٩
Hashimiya	٠.٧٣٣	٠.٧٩٧	٠.٩٢٣	٠.٦٢٥
Hssien	٠.٥٩٢	٠.٦٠٢	٠.٦٠٥	٠.٥٧٠

Matrix A

Pollutant	Ha			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٦٤٧	٠.٠١١	٠.٢٣١	٠.٠٦٠
Hindiya	٠.٠٩٧	٠.٥٨٥	٠.٢٧٥	-٠.٠٠٣
Hashimiya	-٠.٠٢٤	٠.٠٥٠	٠.٨٦٢	٠.٠٥٩
Hssien	٠.١٧٧	٠.٠٦٩	٠.٢٤٦	٠.٢٥٤

Matrix B

Pollutant	Ha			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٤٥٢	٠.٠٠٠	٠.٠٠٠	٠.٠٠٠
Hindiya	٠.٢٠٩	٠.٣٤٧	٠.٠٠٠	٠.٠٠٠
Hashimiya	٠.١١٠	٠.٠٩١	٠.٢٩٠	٠.٠٠٠
Hssien	٠.١٦١	٠.١٩٥	٠.٠٩٧	٠.٦٩٧

Table (٣-٤٧): Continued

M٠

Pollutant	Mg			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	١.٠٠٠	٠.٤٠٠	٠.٢٣٦	٠.٢٠٥
Hindiya	٠.٤٠٠	١.٠٠٠	٠.٠٨٢	٠.٤٠٩
Hashimiya	٠.٢٣٦	٠.٠٨٢	١.٠٠٠	٠.٢٤٩
Hssien	٠.٢٠٥	٠.٤٠٩	٠.٢٤٩	١.٠٠٠

M١

Pollutant	Mg			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٢٤٠	٠.١٧٣	٠.٠١٩	٠.٠٧٣
Hindiya	٠.٢٢٦	٠.٤٤٤	-٠.٠٧٩	٠.١٩٧
Hashimiya	٠.١٩٨	٠.١٥٥	٠.١٢٧	٠.١٧٣
Hssien	٠.٢٠١	٠.٤٢٣	٠.١١٥	٠.٤٦٠

Matrix A

Pollutant	Mg			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٢١٣	٠.٠٩٠	-٠.٠٣٩	٠.٠٠٢
Hindiya	٠.٠٩٠	٠.٣٩٩	-٠.١٤٦	٠.٠٥١
Hashimiya	٠.١٤٠	٠.٠٥٠	٠.٠٦٣	٠.١٠٨
Hssien	٠.٠٢٠	٠.٢٧٤	٠.٠٠٢	٠.٣٤٣

Matrix B

Pollutant	Mg			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٩٦٦	٠.٠٠٠	٠.٠٠٠	٠.٠٠٠
Hindiya	٠.٣١٨	٠.٨٣٤	٠.٠٠٠	٠.٠٠٠
Hashimiya	٠.١٩١	-٠.٠٦١	٠.٩٤٧	٠.٠٠٠
Hssien	٠.١٣٢	٠.٢٠٩	٠.١٣٦	٠.٨٠١

Table (٣-٤٧): Continued

M٠

Pollutant	TDS			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	١.٠٠٠	٠.٦٤٨	٠.٤٥٩	٠.٣٧٨
Hindiya	٠.٦٤٨	١.٠٠٠	٠.٤٩٤	٠.٢٨٧
Hashimiya	٠.٤٥٩	٠.٤٩٤	١.٠٠٠	٠.١٥٣
Hssien	٠.٣٧٨	٠.٢٨٧	٠.١٥٣	١.٠٠٠

M١

Pollutant	TDS			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٧٨٥	٠.٥٧١	٠.٣٨٣	٠.٢٥٩
Hindiya	٠.٦١٤	٠.٨٠٠	٠.٣٩٣	٠.٢٧٥
Hashimiya	٠.٣٦٤	٠.٤٧٠	٠.٥٦٢	٠.١٥٠
Hssien	٠.٣٤٢	٠.٢٦٧	٠.٠٧٥	٠.٦١١

Matrix A

Pollutant	TDS			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٧٣٣	٠.١١١	-٠.٠٠١	-٠.٠٥٠
Hindiya	٠.١٦٩	٠.٧٠٤	-٠.٠٣٥	٠.٠١٥
Hashimiya	-٠.٠٠٧	٠.٢٥٦	٠.٤٣٧	٠.٠١٢
Hssien	٠.١٣٣	٠.٠٧٥	-٠.١٠٨	٠.٥٥٦

Matrix B

Pollutant	TDS			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٦١١	٠.٠٠٠	٠.٠٠٠	٠.٠٠٠
Hindiya	٠.٢٠١	٠.٥٥٠	٠.٠٠٠	٠.٠٠٠
Hashimiya	٠.٢٤٣	٠.١٢٧	٠.٧٤٧	٠.٠٠٠
Hssien	٠.٢٠٩	-٠.٠١٣	-٠.٠٠٤	٠.٧٤٧

Table (3-47): Continued

M.

Pollutant	Tu			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	1.000	0.047	0.024	0.020
Hindiya	0.047	1.000	0.332	0.312
Hashimiya	0.024	0.332	1.000	0.000
Hssien	0.020	0.312	0.000	1.000

M'

Pollutant	Tu			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	0.032	0.036	0.378	0.430
Hindiya	0.401	0.380	0.207	0.390
Hashimiya	0.333	0.434	0.602	0.400
Hssien	0.298	0.244	0.391	0.448

Matrix A

Pollutant	Tu			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	0.224	0.341	0.043	0.187
Hindiya	0.190	0.228	-0.130	0.299
Hashimiya	-0.199	0.318	0.612	0.071
Hssien	-0.020	0.092	0.193	0.326

Matrix B

Pollutant	Tu			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	0.774	0.000	0.000	0.000
Hindiya	0.310	0.804	0.000	0.000
Hashimiya	0.200	0.068	0.600	0.000
Hssien	0.300	0.007	0.266	0.702

Table (٣-٤٧): Continued

M٠

Pollutant	Q			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	١.٠٠٠	٠.٥٦٥	٠.٥٨٠	٠.٤٨٢
Hindiya	٠.٥٦٥	١.٠٠٠	٠.٤٣٨	٠.٢٨٣
Hashimiya	٠.٥٨٠	٠.٤٣٨	١.٠٠٠	٠.٥٢٩
Hssien	٠.٤٨٢	٠.٢٨٣	٠.٥٢٩	١.٠٠٠

M١

Pollutant	Q			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٤٥٠	٠.٣٥٣	٠.١٦٢	-٠.٠٠٣
Hindiya	٠.٤١٥	٠.٥٤٧	٠.٢٦٣	٠.١٦٢
Hashimiya	٠.٣٣٧	٠.٢٧٥	٠.٣٣٣	-٠.٠٢٢
Hssien	٠.١٨٤	٠.١٦٣	-٠.٠٠٦	-٠.٠٤٣

Matrix A

Pollutant	Q			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٥٣٠	٠.١٦٢	-٠.٠٧٦	-٠.٢٦٤
Hindiya	٠.١٩١	٠.٤٦٤	-٠.٠٢٥	-٠.٠٤٨
Hashimiya	٠.٤٥٠	٠.١٦٠	-٠.٢٠٤	-٠.١٧٦
Hssien	٠.٢٦٤	٠.١١٢	-٠.١٤٠	-٠.١٢٨

Matrix B

Pollutant	Q			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٨٤٦	٠.٠٠٠	٠.٠٠٠	٠.٠٠٠
Hindiya	٠.٣٧٦	٠.٧٣٤	٠.٠٠٠	٠.٠٠٠
Hashimiya	٠.٤١٧	٠.١١٩	٠.٧٨٦	٠.٠٠٠
Hssien	٠.٤٠٨	٠.٠٢١	٠.٣٠٢	٠.٨١٧

Table (٣-٤٨): Matrices for multi sites model (M., M<sub>1</sub>, A, B) for all pollutants at four stations (water supply)

M.

Pollutant	Alk			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	١.٠٠٠	١.٤٥٧	٠.٥٢٥	٠.٤٢٠
Hindiya	٠.٤٥٧	١.٠٠٠	٠.٥٨٤	٠.٥٨٣
Hashimiya	٠.٥٢٥	٠.٥٨٤	١.٠٠٠	٠.٥٢٧
Hssien	٠.٤٢٠	٠.٥٨٣	٠.٥٢٧	١.٠٠٠

M<sub>1</sub>

Pollutant	Alk			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٥٦٩	٠.٣٢٠	٠.٤٣٢	٠.٣٦٠
Hindiya	٠.٤٥٦	٠.٦٤٩	٠.٦١٩	٠.٥٦٢
Hashimiya	٠.٤٢٨	٠.٤٣٣	٠.٦٤٦	٠.٤٠١
Hssien	٠.٣٨٧	٠.٤٠٩	٠.٥٢٩	٠.٦٦٦

Matrix A

Pollutant	Alk			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٤٦١	-٠.٠٤٩	٠.١٦١	٠.١١٠
Hindiya	٠.٠٧٤	٠.٣٤٣	٠.٢٨٥	٠.١٨١
Hashimiya	٠.١٠٥	٠.٠٤٠	٠.٥٤٣	٠.٠٤٧
Hssien	٠.٠٥٩	-٠.٠٩٦	٠.٢٦٠	٠.٥٦٠

Matrix B

Pollutant	Alk			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٨٠٢	٠.٠٠٠	٠.٠٠٠	٠.٠٠٠
Hindiya	٠.١٤٧	٠.٦٦٦	٠.٠٠٠	٠.٠٠٠
Hashimiya	٠.٢٥٠	٠.١٦٥	٠.٦٩١	٠.٠٠٠
Hssien	٠.١٢٨	٠.١٨٦	٠.١٢٥	٠.٦٦٢

Table (٣-٤٨): Continued

M٠

Pollutant	Ca			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	١.٠٠٠	٠.٨٤١	٠.٨٢٩	٠.٧٧٣
Hindiya	٠.٨٤١	١.٠٠٠	٠.٧٩٩	٠.٦٩١
Hashimiya	٠.٨٢٩	٠.٧٩٩	١.٠٠٠	٠.٧٤٩
Hssien	٠.٧٧٣	٠.٦٩١	٠.٧٤٩	١.٠٠٠

M١

Pollutant	Ca			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٨٥٣	٠.٧٦٠	٠.٧٤٩	٠.٧٣٧
Hindiya	٠.٧٣٢	٠.٨٣١	٠.٧٤٢	٠.٦٥٨
Hashimiya	٠.٧٥٩	٠.٧٠٩	٠.٨١١	٠.٧٠٨
Hssien	٠.٧٢٠	٠.٦٩٣	٠.٧١٩	٠.٨٤٨

Matrix A

Pollutant	Ca			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٥٩٤	٠.١٠٩	٠.٠٤١	٠.١٧٢
Hindiya	-٠.٠٥٤	٠.٦٥٨	٠.١٧٨	٠.١١٣
Hashimiya	٠.١٧٧	٠.٠٤١	٠.٥١٣	٠.١٥٩
Hssien	-٠.٠٣٠	٠.٤٦٨	٠.١٠١	٠.٦٨٠

Matrix B

Pollutant	Ca			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٥٠٢	٠.٠٠٠	٠.٠٠٠	٠.٠٠٠
Hindiya	٠.٣٣٩	٠.٤١٥	٠.٠٠٠	٠.٠٠٠
Hashimiya	٠.٢٨٨	٠.١٢٧	٠.٤٥٧	٠.٠٠٠
Hssien	٠.١٨٦	-٠.٠٢٨	٠.٠٨٦	٠.٤٦١

**Table (٣-٤٨): Continued**

**M٠**

Pollutant	Cl			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	١.٠٠٠	٠.٨٥٠	٠.٨١٧	٠.٧٧٨
Hindiya	٠.٨٥٠	١.٠٠٠	٠.٨١١	٠.٨١٢
Hashimiya	٠.٨١٧	٠.٨١١	١.٠٠٠	٠.٧٦٨
Hssien	٠.٧٧٨	٠.٨١٢	٠.٧٦٨	١.٠٠٠

**M١**

Pollutant	Cl			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٩٢١	٠.٧٩٣	٠.٧٩٦	٠.٧٥٦
Hindiya	٠.٨٢٠	٠.٩٠٠	٠.٨٠١	٠.٧٧٠
Hashimiya	٠.٧٧٨	٠.٧٥٢	٠.٩١٨	٠.٧٠٥
Hssien	٠.٧٤٩	٠.٧٥٤	٠.٧٥٩	٠.٨٠٢

**Matrix A**

Pollutant	Cl			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٨٠٩	-٠.٠٥٥	٠.١١٨	٠.٠٧٩
Hindiya	٠.١١٩	٠.٦٤٧	٠.١٥٢	٠.٠٣٦
Hashimiya	٠.١١١	-٠.٠٢١	٠.٨٦٨	-٠.٠٣١
Hssien	٠.١٤٠	٠.٠٨١	٠.٢٣٦	٠.٤٤٧

**Matrix B**

Pollutant	Cl			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٣٧٩	٠.٠٠٠	٠.٠٠٠	٠.٠٠٠
Hindiya	٠.٢٠٨	٠.٣٥٧	٠.٠٠٠	٠.٠٠٠
Hashimiya	٠.١٦٨	٠.٠٨٩	٠.٣٤٢	٠.٠٠٠
Hssien	٠.١٥٨	٠.١٦٥	٠.٠٧٤	٠.٤٨٨

Table (٣-٤٨): Continued

M٠

Pollutant	EC			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	١.٠٠٠	٠.٨٤٦	٠.٨٢٤	٠.٧٣٩
Hindiya	٠.٨٤٦	١.٠٠٠	٠.٨٤٨	٠.٧٦٠
Hashimiya	٠.٨٢٤	٠.٨٤٨	١.٠٠٠	٠.٧٨٠
Hssien	٠.٧٣٩	٠.٧٦٠	٠.٧٨٠	١.٠٠٠

M١

Pollutant	EC			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٨٧٠	٠.٧٣٣	٠.٧٣٣	٠.٦٥١
Hindiya	٠.٨٠٦	٠.٨١٧	٠.٧٩٢	٠.٧٠١
Hashimiya	٠.٧٧٢	٠.٧٥٢	٠.٨٣٩	٠.٧١١
Hssien	٠.٧٢٥	٠.٦٩٦	٠.٧١٤	٠.٨٣١

Matrix A

Pollutant	EC			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٨٥٠	-٠.٠٥٣	٠.٠٧٢	٠.٠٠٧
Hindiya	٠.٣٠٦	٠.٣٣٩	٠.٢١٠	٠.٠٥٣
Hashimiya	٠.٢٢٤	-٠.٠٠٤	٠.٥٨٧	٠.٠٩٠
Hssien	٠.٢٤٧	-٠.٠٣٦	٠.٠٣٦	٠.٦٤٨

Matrix B

Pollutant	EC			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٤٩١	٠.٠٠٠	٠.٠٠٠	٠.٠٠٠
Hindiya	٠.٢٩٠	٠.٤٣٣	٠.٠٠٠	٠.٠٠٠
Hashimiya	٠.٢٩٠	٠.١٣٢	٠.٠٧٦	٠.٠٠٠
Hssien	٠.٢٨٨	٠.٤٣٦	-٠.٢٠٨	٠.٠٠٠

Table (٣-٤٨): Continued

M.

Pollutant	Ha			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	١.٠٠٠	٠.٧٦١	٠.٧٥٤	٠.٦٩٣
Hindiya	٠.٧٦١	١.٠٠٠	٠.٨٥٤	٠.٦٢٥
Hashimiya	٠.٧٥٤	٠.٨٥٤	١.٠٠٠	٠.٦٨٥
Hssien	٠.٦٩٣	٠.٦٢٥	٠.٦٨٥	١.٠٠٠

M١

Pollutant	Ha			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٨٢٨	٠.٧٢٠	٠.٧٤٩	٠.٧٠٣
Hindiya	٠.٧٤٧	٠.٨٩٠	٠.٨٥٨	٠.٦٣٧
Hashimiya	٠.٧٠٧	٠.٨٠٤	٠.٩٢٦	٠.٦٤٦
Hssien	٠.٦١٦	٠.٦٠٠	٠.٧٠٥	٠.٧٤١

Matrix A

Pollutant	Ha			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٥٢٤	٠.٠٤٣	٠.١٩٤	٠.١٨٠
Hindiya	٠.٠٧٤	٠.٥٤٥	٠.٣١٩	٠.٠٢٦
Hashimiya	٠.٠٠٢	٠.٠٤٥	٠.٨٧٥	٠.٠١٧
Hssien	٠.٠٢٢	-٠.٠٨٨	٠.٤٣٠	٠.٤٨٦

Matrix B

Pollutant	Ha			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٥١٣	٠.٠٠٠	٠.٠٠٠	٠.٠٠٠
Hindiya	٠.٠٩٧	٠.٣٩٩	٠.٠٠٠	٠.٠٠٠
Hashimiya	٠.١٠١	٠.١٠٣	٠.٣٤٦	٠.٠٠٠
Hssien	٠.١٤٥	-٠.٠١٦	٠.٠٤٢	٠.٥٩٣

Table (٣-٤٨): Continued

M·

Pollutant	Mg			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	١.٠٠٠	٠.٥٠١	٠.٥٧٢	٠.٢٧٨
Hindiya	٠.٥٠١	١.٠٠٠	٠.٥١٩	٠.٢٤٣
Hashimiya	٠.٥٧٢	٠.٥١٩	١.٠٠٠	٠.٣٧٤
Hssien	٠.٢٧٨	٠.٢٤٣	٠.٣٧٤	١.٠٠٠

M١

Pollutant	Mg			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٦٦٩	٠.٣٦٤	٠.٣٩٧	٠.١٥٨
Hindiya	٠.٤٤٨	٠.٧٤٩	٠.٤٢٩	٠.١٧٧
Hashimiya	٠.٥١٦	٠.٤٦٠	٠.٦٠٠	٠.١٥٧
Hssien	٠.٢٧١	٠.٢٩١	٠.٣٢٦	-٠.١٠٨

Matrix A

Pollutant	Mg			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٦٥٠	٠.٠٣٩	٠.٠١٩	-٠.٠٤٠
Hindiya	٠.٠٩٣	٠.٦٩٧	٠.٠٢٥	-٠.٠٢٧
Hashimiya	٠.٢٢٢	٠.١٤٨	٠.٤٣٥	-٠.١٠٤
Hssien	٠.١٠٥	٠.١٥٧	٠.٢٩١	-٠.٢٨٤

Matrix B

Pollutant	Mg			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٧٤٠	٠.٠٠٠	٠.٠٠٠	٠.٠٠٠
Hindiya	٠.٢٤١	٠.٦٠٩	٠.٠٠٠	٠.٠٠٠
Hashimiya	٠.٢٨٨	٠.١١٥	٠.٦٨٩	٠.٠٠٠
Hssien	٠.١٠٧	-٠.٠٣٧	٠.١٣٠	٠.٨٧٨

Table (٣-٤٨): Continued

M٠

Pollutant	TDS			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	١.٠٠٠	٠.٣٣٠	٠.١٩٦	٠.١٣١
Hindiya	٠.٣٣٠	١.٠٠٠	٠.٦٤٠	٠.٣٩٣
Hashimiya	٠.١٩٦	٠.٦٤٠	١.٠٠٠	٠.٥٠٤
Hssien	٠.١٣١	٠.٣٩٣	٠.٥٠٤	١.٠٠٠

M١

Pollutant	TDS			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.١١٩	٠.٣٧٨	٠.٢٢١	٠.١٥٣
Hindiya	٠.٢٤٧	٠.٧٩٧	٠.٥٧٦	٠.٣٧٧
Hashimiya	٠.٢٣٧	٠.٥٦١	٠.٧٤٩	٠.٤٦٠
Hssien	٠.٠٧٠	٠.٣٤٥	٠.٤٤٧	٠.٦٣٦

Matrix A

Pollutant	TDS			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	-٠.٠٠٨	٠.٤٠١	-٠.٠٤٣	٠.٠١٨
Hindiya	-٠.٠١٦	٠.٧٢٥	٠.٠٩٠	٠.٠٤٨
Hashimiya	٠.٠٦٩	٠.١٠٣	٠.٦٢٠	٠.٠٩٨
Hssien	-٠.٠٤٧	٠.٠٥٠	٠.١٤٨	٠.٥٤٧

Matrix B

Pollutant	TDS			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٩٢٥	٠.٠٠٠	٠.٠٠٠	٠.٠٠٠
Hindiya	٠.٠٣٣	٠.٥٩٥	٠.٠٠٠	٠.٠٠٠
Hashimiya	-٠.٠٠٥	٠.٢٤٧	٠.٥٩٥	٠.٠٠٠
Hssien	٠.٠٠١	٠.١٢٢	٠.١٥٧	٠.٧٢٩

Table (٣-٤٨): Continued

M.

Pollutant	Tu			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	١.٠٠٠	٠.٠٨٠	٠.٠٥٩	٠.٠١٩
Hindiya	٠.٠٨٠	١.٠٠٠	٠.٠٦٦	-٠.٠٥٥
Hashimiya	٠.٠٥٩	٠.٠٦٦	١.٠٠٠	٠.٠٩٦
Hssien	٠.٠١٩	-٠.٠٥٥	٠.٠٩٦	١.٠٠٠

M١

Pollutant	Tu			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٥١٧	٠.٠٩٦	٠.٠٩٨	-٠.٠٠١
Hindiya	-٠.٠٠١	-٠.٤٠٤	٠.٠٦٠	٠.٠٥٥
Hashimiya	٠.٠٤٠	٠.٠١٢	٠.٥٠٧	٠.٢٢٦
Hssien	-٠.٠٠٨	٠.١٥٣	٠.٢٦٢	٠.١٣٧

Matrix A

Pollutant	Tu			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٥٠٩	٠.٠٥١	٠.٠٦٦	-٠.٠١٤
Hindiya	٠.٠٢٦	-٠.٤١٠	٠.٠٨٣	٠.٠٢٤
Hashimiya	٠.٠٠٩	-٠.٠١١	٠.٤٩١	٠.١٧٩
Hssien	-٠.٠٣٧	٠.١٤٧	٠.٢٤٢	٠.١٢٣

Matrix B

Pollutant	Tu			
Station	Hilla	Hindiya	Hashimiya	Hssien
Hilla	٠.٨٥٢	٠.٠٠٠	٠.٠٠٠	٠.٠٠٠
Hindiya	٠.١١٥	٠.٩٠٢	٠.٠٠٠	٠.٠٠٠
Hashimiya	٠.٠٠٩	٠.٠٢٤	٠.٨٤٢	٠.٠٠٠
Hssien	٠.٠٠٠	-٠.٠١٩	-٠.٠٦٥	٠.٩٤٤



## Chapter Two

### Theory and Literature Review

#### A: Theory:

#### 2.1: Time Series Components and Properties:

Time series is defined as a set of observations generated sequentially in time ( $X_t : t \in T$ ) [1].

A time series is said to be continuous when some variables ( $X_t$ ) can be observed continuously, i.e. the time ( $t$ ) can take all the values in an interval of real numbers and said to be discrete when the set of the possible values ( $t$ ) is a discrete set, i.e. ( $T$ ) can be viewed as a subset of the integers [1]. Thus, the observations from a discrete time series are usually expressed as an average value over equal intervals of time such as mean daily, mean monthly, or mean annual data.

#### 2.1.1: Components of Time Series:

Generally, a time series can be expressed as a linear combination of four components depending on the type of variable and the averaging time interval. These components may exist in monthly time series which are represented in the form:

$$X_t = J_t + T_t + P_t + \varepsilon_t \dots\dots\dots (2-1)$$

Where:

$X_t$ : Time series observations at time  $t = 1, 2, 3, \dots, N$ .

$J_t$ : Jump component.

$T_t$ : Trend component.

$P_t$ : Periodic component.

$\varepsilon_t$ : Stochastic component.

$N$ : No. of observations.

Time series analysis involves the decomposition of the series into constituent components.

The first three components represent the deterministic part which are exactly determined by some mathematical function, while the fourth component represents the non-deterministic part (stochastic part) which is described only in terms of the probability distribution. Fig. (2-1) shows the four time series components

### 2.1.2: Homogeneity of Time Series:

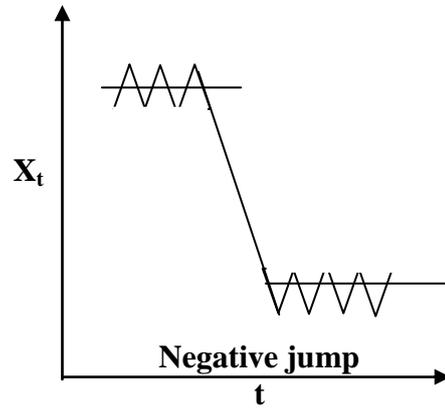
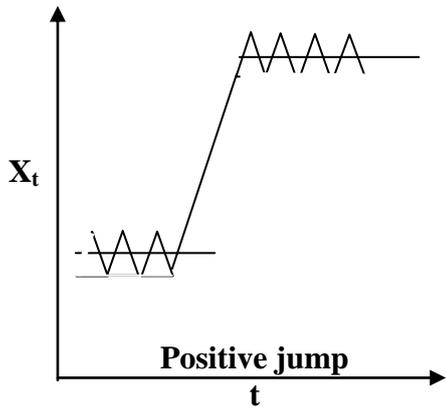
Prior to any analysis it is essential to verify that the series is homogeneous by detection and removal of jump and trend components. Homogeneity definition requires at least two conditions:

- 1 - The data series is free from any systematic error.
- 2 - All the conditions of series should be constant.

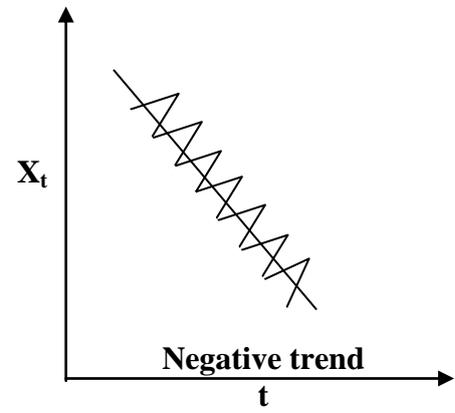
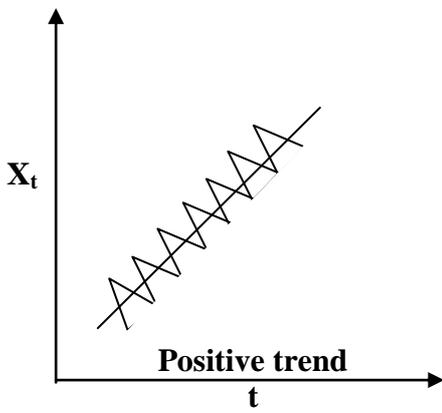
The series may be considered as homogeneous if these conditions are satisfied. Homogeneity implies a time invariant mean and therefore, tests to check its prevalence are based on evaluating the significance of change in mean value [1].

### 2.1.3: Stationarity:

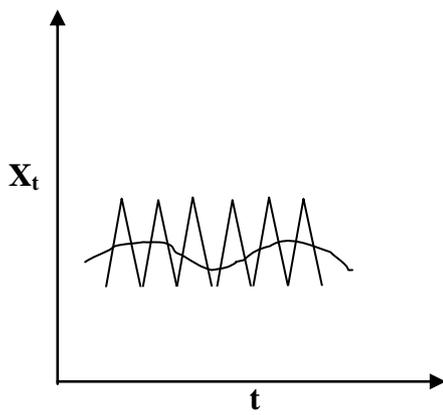
A very special class of time series, called stationary process, is based on the assumption that the process is a particular state of statistical equilibrium. A series, once found to be homogeneous, should also be tested for its stationarity. Because strict stationarity is only a mathematical concept, it is often necessary for practical purposes to restrict the conditions of stationarity to the mean and the variance only [1].



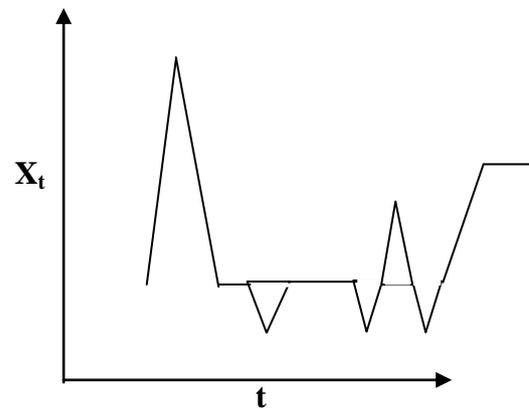
$$X_t = j_t + P_t + \varepsilon_t$$



$$X_t = T_t + P_t + \varepsilon_t$$



$$X_t = P_t + \varepsilon_t$$



$$X_t = \varepsilon_t$$

Fig. (2-1) The Components of time series

If it's seasonal (monthly, weekly, daily) means are constant with time then it is considered to be first order stationarity. If standard deviations are also constant with time, then it is considered as second order stationarity and so on.

First order stationary may be found by subtracting the mean of each period from the series as shown below:

$$Y_{j,t}^* = Y_{j,t} - M_t \dots\dots\dots (r-2)$$

Where:

$Y_{j,t}^*$  : First order stationary series at year (j) and month (t).

$Y_{j,t}$  : Value of homogeneous, non – stationary series.

$M_t$  : Mean at month (t), week, or day.

To obtain second order stationarity, equation (r-2) is divided by the standard deviation for each period.

$$Z_{j,t} = \frac{Y_{j,t} - M_t}{S_t} \dots\dots\dots (r-3)$$

Where:

$Z_{j,t}$  : Second order stationary series.

$S_t$  : Standard deviation of month (t), week, or day.

The application of equation (r-3) is also called standarization Which gives a series ( $Z_{j,t}$ ) with zero mean and unit variance. Second order stationary is commonly used for the analysis time series. Finally, stationarity implies that the statistical parameters of the series computed from different samples do not change except due to sampling variations and it is important to mention that the stationary series is homogeneous.

### 2.1.4: Jump and Trend Components:

Many authors define the jump component as a trend component, while these two components differ somehow from each other [4]. The jump component may be defined precisely as a sudden slippage (either negative or positive) in the statistical parameters of the historical data such as mean, standard deviations ...etc. This component usually results from the activities of citizens, for example, the construction of factories or drains upstream of the observation station, will cause a positive jump in pollution levels, while shifting the industrial waste water and drainage water away from the point of observation may result in negative jump.

Trend component is defined as a growth or decay that is the tendencies for data to increase or decrease fairly steadily over time[6] or defines as whether water quality which is getting better or worse[31] state in any parameter of the series. The main causes of trend in water quality data are either sequential man-made change within the catchment area (such as extensive urban development), or natural causes (such as climatic change).

Among many tests available to detect trend and jump in time series are the turning point test, Kendall's Rank Correlation test [19] and split-sample method.

#### **a – Turning Point Test:**

This test is based on the fact that too many or too few turning points indicate non-randomness [11]. In the observed sequence of  $(X_i)$ , a turning point (P) in series occurs at time  $(t = i)$ , if  $(X_i)$  is either greater than  $(X_{i-1})$  and  $(X_{i+1})$  or less than the two adjacent values. The expected number of turning points (P) in the random series is  $(\bar{P})$ :

$$\bar{P} = \frac{2(N-2)}{3} \dots\dots\dots (2-4)$$

Where N : Number of observations.

Variance ( $\bar{P}$ ) can be computed as:

$$\text{var}(\bar{P}) = \frac{(16N - 29)}{90} \dots\dots\dots (\gamma - 5)$$

the number of turning point (P) in a series is expressed as a standard normal variate in the form:

$$Z = \frac{P - \bar{P}}{\sqrt{\text{var}(\bar{P})}} \dots\dots\dots (\gamma - 6)$$

**b – Kendall’s Rank Correlation Test:**

Kendall’s Rank test statistically evaluates the trend of a series by computing the number of times (P) in all pairs of observation  $X_i, X_j (j > i)$  that  $X_j > X_i$ . The test is carried out using the statistic ( $\tau$ ) defined as:

$$\tau = \frac{4P}{N(N-1)} - 1 \dots\dots\dots (\gamma - 7)$$

The statistic is then expressed as a standard normal variate in the form:

$$Z = \frac{\tau - \bar{\tau}}{\sqrt{\text{var}(\bar{\tau})}} \dots\dots\dots (\gamma - 8)$$

Where ( $\bar{\tau}$ ): The expected value of ( $\tau$ ) if the series is random ( $\cdot$ , if random).

$$\text{var}(\bar{\tau}) = \frac{2(2N + 5)}{9N(N-1)} \dots\dots\dots (\gamma - 9)$$

The computed standard normal variate is then compared with it’s table value at a given level of significance. If the calculated value of ( $Z$ ) is within the limits the hypothesis of no-trend is accepted. If a trend is detected, it can be removed by fitting a linear regression equation.

**c – Split – Sample Method:**

This method is the most powerful for testing homogeneity which is suggested by YeVjevich [ε]. It is carried out by dividing the series of the data into two sub-samples. Then the mean and standard deviation of each sub-

sample were computed and used for testing the difference between these two sub-samples at the ( 95.0 % ) probability level of significance by using the (t-test).

This method is used mostly for the detection jump component, but it may be also used for detection of trend component when the trend is steep enough to produce high difference in the same statistical parameters (mean, standard deviation) for two sub-samples.

For non-homogeneity arises due to changes in the method of data collection and the environment which is done, Yevjevich suggests fitting linear regression equations for both annual means and annual standard deviations as follows:

$$Y_{j,t} = \frac{X_{j,t} - \bar{X}_j}{S_j} Sd_2 + A v_2 \dots\dots\dots (2-10)$$

Where:

j, t : Annual and monthly position of observation, respectively.

Y : Transformed series (homogeneous).

X : Historical non – homogeneous series.

$A v_2, Sd_2$  : Mean and standard deviation of the second sub-sample respectively (Future sub-sample).

$\bar{X}_j, S_j$  : Linear regression equations for annual means and standard deviations against year, which are expressed as follows:

$$\bar{X}_j = A + B_j \dots\dots\dots (2-11)$$

$$S_j = A_1 + B_{1j} \dots\dots\dots (2-12)$$

Where:  $\bar{X}_j$  : Annual means at year (j).

$S_j$  : Annual standard deviation at year (j).

A, B,  $A_1$ ,  $B_{1j}$  : Regression coefficients.

### ۲.۱.۵: **Periodic Component:**

This component is defined as a regular fluctuation which is repeated from year to year with about the same timing and level of intensity (for example, each month, or each day ...etc.) [۱].

Cyclic behavior may appear in more than one statistical parameter such as mean, standard deviation, skewness, kurtosis and serial correlation coefficients.

Detection of periodicity can be made by the auto-correlation and spectral analysis [۲].

### ۲.۱.۵ (a): **Auto-Correlation Analysis:**

For random variables or observation the auto-correlation coefficients must theoretically equal to zero [۳].

In the auto-correlation analysis, the existence of the periodic component may be detected by investigating the correlogram (see sec. ۲.۱.۶) of the data. If the series is periodic, the auto-correlogram will also be periodic, otherwise it is not.

The classical two approaches to description and removal of periodicity in basic parameters of hydrologic and other geophysical time series are here termed as follows:

### **a-۱: The Non – Parametric (Non Functional) Approach:**

This approach is appropriate for simulation of stationary unregulated water quality data inputs that are needed in simulation studies to analyze alternative designs, operation policies, and rates for water resources systems[۴].

It is necessary to remove any seasonlity (periodicity) in the historical data. A common procedure employed in hydrology for monthly sequences is

to deseasonalize the series by subtracting the estimated monthly mean and dividing by the estimated monthly standard deviation for each data [ $\epsilon$ ] as follows:

$$\epsilon_{j,t} = \frac{X_{j,t} - \bar{X}_t}{S_t} \dots\dots\dots (2-13)$$

Where:

$\epsilon_{j,t}$ : Dependent stochastic component of  $(X_{j,t})$  at year (j) and month (t).

$\bar{X}_t, S_t$ : Samples mean and standard deviations of  $(X_{j,t})$  at month (t) which were computed by :

$$\bar{X}_t = \frac{1}{n} \sum_{j=1}^n X_{j,t} \dots\dots\dots (2-14)$$

$$S_t = \left[ \frac{1}{n-1} \sum_{j=1}^n (X_{j,t} - \bar{X}_t)^2 \right]^{1/2} \dots\dots\dots (2-15)$$

Where (n): Number of years.

The removal of periodicity in  $(\bar{X}_t)$  and  $(S_t)$  by equation (2-13) is equivalent to the standardization of  $(X_{j,t})$  series in equation (2-3).

**a-4: The Parametric Approach:**

If a periodicity exists in a trend free series, it can be removed by representing it by a Fourier series of the form:

$$m_t = m_0 + \sum_{j=1}^h C_j \cos \left( \frac{2\pi jt}{w} + \theta_j \right) \dots\dots\dots (2-16)$$

Where:

$m_t$ : Harmonically fitted means, variance or any parameter at month t (t= 1, 2, 3, ... w).

$m_0$ : Population mean of  $(m_t)$ .

h: Total number of harmonics  $\left( = \frac{w}{2} \text{ or } \frac{(w+1)}{2} \right)$  depending on whether (w) is even or odd).

w : Time span of periodicity (for monthly data  $w = 12$ ).

$C_j, \theta_j$ : Amplitude and the phase of the (jth) harmonic, respectively.

An alternative form of equation (2-17) may be used:

$$m_t = m_0 + \sum_{j=1}^h \left( A_j \cos \left( \frac{2\pi jt}{w} \right) + B_j \sin \left( \frac{2\pi jt}{w} \right) \right) \dots\dots\dots (2-17)$$

$A_j, B_j$ : Fourier coefficients which are defined as:

$$A_j = \left( \frac{2}{w} \right) \sum_{t=1}^w m_t \cos \left( \frac{2\pi jt}{w} \right) \dots\dots\dots (2-18)$$

$$B_j = \left( \frac{2}{w} \right) \sum_{t=1}^w m_t \sin \left( \frac{2\pi jt}{w} \right) \dots\dots\dots (2-19)$$

the amplitude ( $C_j$ ) and phase ( $\theta_j$ ) are calculated by:

$$C_j = \sqrt{A_j^2 + B_j^2} \dots\dots\dots (2-20)$$

$$\theta_j = \tan^{-1} \left( \frac{B_j}{A_j} \right) \dots\dots\dots (2-21)$$

For monthly data ( $w=12$ ) and therefore the maximum number of harmonic (h) is  $\left( \frac{w}{2} = 6 \right)$ . When w is even then:

$$A_{\frac{w}{2}} = \frac{1}{w} \sum_{t=1}^w m_t \cos \pi t \dots\dots\dots (2-22)$$

$$B_{\frac{w}{2}} = 0 \dots\dots\dots (2-23)$$

The use of the Fourier series requires careful judgment in estimation of significant harmonics in periodic functions which describe the basic parameters of hydrologic time series. There is a need for more accurate methods of estimating the significant harmonic in the Fourier description[ ],

so that the empirical method which is also called the critical explained variance method was used for this estimation.

The ratio  $(\Delta P_j)$  calculated by:

$$\Delta P_j = \frac{(A_j^2 + B_j^2)/2}{\text{var} \cdot m_t} \dots\dots\dots (\gamma - \gamma \epsilon)$$

This ratio represents the part of variance of  $(m_t)$  which is explained by the  $(j)$ th harmonic. These ratios  $(\Delta P_j)$  are then ranked in descending ordered sequence and assumed to:

$$P_j = \sum_{i=1}^j P_i \quad \text{for} \left( j=1, 2, \dots, \frac{w}{2} \right) \dots\dots\dots (\gamma - \gamma \circ)$$

Where  $(P_j)$  is the variance explained by  $(j)$  harmonics.

For most hydrological series the harmonics of any parameter are usually not significant beyond the first  $w/\gamma$  harmonics, so  $(P_{w/2})$  is calculated from equation  $(\gamma - \gamma \circ)$  and then:

- a- If  $P_{w/2} < P_{\min}$ , then no harmonic is significant.
- b- If  $P_{\min} < P_{w/2} < P_{\max}$ , then all harmonic are significant.
- c- If  $P_{w/2} > P_{\max}$ , then the first  $(j)$  harmonic whose  $(P_j)$  value first exceed  $(P_{\max})$  are significant where the critical values  $(P_{\min})$  and  $(P_{\max})$  are calculated from:

$$P_{\min} = a \sqrt{\frac{w}{n c}} \dots\dots\dots (\gamma - \gamma \tau)$$

$$P_{\max} = 1 - P_{\min} \dots\dots\dots (\gamma - \gamma \nu)$$

respectively, where:

C: Order of the highest moment used in estimating the parameter  $(m_t)$ .

w: Number of seasons.

n: Number of years.

a: Constant which is suggested to be  $(\dots \gamma \tau)$  by Yevjevich $[\gamma \tau]$ .

2.1.6 (b): Spectral Analysis:

This method is used to detect the existence of the periodic component as well as Auto-Correlation analysis by using the spectral density function of a given time series.

Spectral analysis is mainly concerned with purely non-deterministic processes, but the technique can also be used for deterministic processes to pick out periodic components in the presence of noise [7].

A popular type of estimating the spectral density function consists of taking a Fourier transform as equal to the covariance of continuous series. For a real discrete process, the estimate of the spectral density  $f(\omega)$  is given as:

$$f(\omega) = \frac{1}{2\pi} \left( C_0 D_0 + 2 \sum_{k=1}^{m-1} C_k D_k \cos(\omega k) + C_m D_m \right) \dots\dots\dots (2-28)$$

Where:

$f(\omega)$ : Spectral density in variance per cycle, per month.

$\omega$  : Frequency in cycle per month.

$m$  : Maximum number of lags.

$C_k$ : Covariance at lag  $k$  which is estimated by:

$$C_k = \frac{1}{N-K} \sum_{t=1}^{N-K} X_t \cdot X_{t+k} - \frac{1}{(N-K)^2} \cdot \sum_{t=1}^{N-K} X_{t+k} \dots\dots\dots (2-29)$$

Where:

$X$ : Value of series observation.

$N$ : Total number of data.

$D_k$ : Van Hann smoothing coefficient suggested by Blank-Mann and Tukey[8], using Kernal function:

$$D_k = \begin{cases} \frac{1}{2} \left( 1 + \cos \frac{\pi k}{m} \right) & |k| > m \\ = 0 & |k| < m \end{cases} \dots\dots\dots (2-30)$$

Where:  $K = 0, 1, 2 \dots m$

When the estimates  $f(w)$  are plotted against  $(w)$ , the resulting plot called periodogram. If this plot shows “spikes” or “lines”, then the existence of periodicity is certain.

Quimpo[ε] compared between the auto correlation and spectral analysis and found that the spectral method is very expensive in computer time, without yielding much more information than the conventional, less expensive auto – correlation method.

**۲.۱.۶: Persistency:**

Persistency is the important characteristic of nautral time series. This is the property by which high values tend to follow high values and low values tend to follow low values [۱۹].

A particular method of measuring persistence is through the serial correlation coefficient plot which called the correlogram plot between serial correlation coefficient values ( $r_k$ ) and the lag ( $k$ ) values. The periodic shape of the correlogram of the series indicates the existence of a periodic component in this series.

Thus, the persistence represents the correlation between the values at time  $(t)$  with the values at time  $(t+۱, t+۲, \dots, t+k)$  which is measured by the serial correlation coefficient ( $r_k$ ) using:

$$r_k = \frac{(N-K) \sum_{t=1}^N X_t \cdot X_{t+k} - \sum_{t=1}^N X_t \sum_{t=1}^N X_{t+k}}{\left[ (N-K) \sum_{t=1}^N X_t^2 - \left( \sum_{t=1}^N X_t \right)^2 \right]^{1/2} \dots \dots \dots (۲-۳۱)}$$

$$\bullet \frac{1}{\left[ (N-K) \sum_{t=1}^N X_{t+k}^2 - \left( \sum_{t=1}^N X_{t+k} \right)^2 \right]^{1/2}}$$

- Where:  $r_k$ : Lag  $(k)$  serial correlation coefficient.
- $N$ : Number of data.
- $K$ : Lag in time units.
- $X_t$ : Value at time  $(t)$ .

Thus,  $(r_k)$  indicates the correlations between any value of the series and the value which appears after  $(k)$  time units.

Approximate expressions for  $(r_k)$  estimation which require less computer time than equation  $(2-31)$  are available. Equation  $(2-32)$ , given by Kendall and Stuart, Hall et.al., is known to be both adequate and economical in computer time [ε].

$$r_k = \frac{\frac{1}{N-K} \sum_{t=1}^{N-K} (X_t - \bar{X})(X_{t+k} - \bar{X})}{\frac{1}{N} \sum_{t=1}^N (X_t - \bar{X})^2} \dots\dots\dots (2-32)$$

Where  $(\bar{X})$  is the series mean.

The  $(r_k)$  values for pure random series should be equal to zero, and in practice those  $(r_k)$  values will deviate from zero due to sampling effect. The series is considered to be independent (uncorrelated) at the  $(90\%)$  level, if the computed values of  $(r_k)$  fall inside the following tolerance limits:

$$S = \frac{-1 \pm 1.96 \sqrt{N-3}}{N-2} \dots\dots\dots (2-33)$$

Where  $(N)$ : Number of data.

S: Tolerance limits.

**2.2: Stochastic Component Methods:**

Stochastic component is the remaining part resulting from the separation of periodic component of mean and standard deviation (non-stationarity) from a trend free series (homogeneity)[11]. It is termed as the dependent stochastic component of the process and denoted as  $(\epsilon_{j,t})$ . This series is considered as homogeneous and second order stationary series.

Since correlation exists between successive values of  $(\epsilon_{j,t})$  series, then it may be fitted by a suitable model whose parameters will depend directly or

indirectly on the amount of existing correlation represented by the  $(r_k)$  values. The models are usually represented as the relation between the dependent stochastic component  $(\varepsilon_{j,t})$  and an independent stochastic component  $(\xi_{j,t})$ . These models may be applied for singlesite or multisites.

### 2.2.1: Singlesite Models:

These models are applied to a single time series in one point from which the observations are taken. The most common three basic models that existed in literature are; the auto-regressive model (Markov model), Moving average model (MA) and their combinations model auto-regressive integrated moving average (ARIMA).

#### A: Auto Regressive Model (Markov Model) [AR(P)]:

This model describes the dependence in any stochastic series  $(\varepsilon_{j,t})$  by assuming that each value  $(\varepsilon_{j,t})$  is a combined effect of previous values in addition to an independent stochastic component  $(\xi_{j,t})$  which occurs at the same time of occurrence of  $(\varepsilon_{j,t})$ . The independent series  $(\xi_{j,t})$  is a series of random numbers usually with zero mean and unit variance. The formulation of this model is given as:

$$\varepsilon_{j,t} = \sum_{i=1}^p \alpha_i \varepsilon_{j,t-1} + \sigma \xi_{j,t} \dots\dots\dots (r - r\varepsilon)$$

Where:

P : Order of the model.

$(\alpha, \sigma)$  : Parameters of the model.

In the stationary time series, the dependence can be well approximated by first, second, or third order linear auto-regressive model. The estimation of the first and second order auto-regressive model parameters is shown below:

**1 – First Order Model:**

$$\varepsilon_{j,t} = \alpha_1 \varepsilon_{j,t-1} + \sigma \xi_{j,t} \dots\dots\dots (2-35)$$

Where:

$$\alpha_1 = r_1 \dots\dots\dots (2-36)$$

$$\sigma = \sqrt{1 - \alpha_1^2} \dots\dots\dots (2-37)$$

**2 – Second Order Model:**

$$\varepsilon_{j,t} = \alpha_1 \varepsilon_{j,t-1} + \alpha_2 \varepsilon_{j,t-2} + \sigma \xi_{j,t} \dots\dots\dots (2-38)$$

Where:

$$\alpha_1 = \frac{r_1 - r_1 r_2}{1 - r_1^2} \dots\dots\dots (2-39)$$

$$\alpha_2 = \frac{r_2 - r_1^2}{1 - r_1^2} \dots\dots\dots (2-40)$$

$$\sigma = 1 - \sqrt{(\alpha_1^2 + \alpha_2^2 + 2\alpha_1 \alpha_2 r_1)} \dots\dots\dots (2-41)$$

**B – Moving Average Model [MA(q)]:**

Another kind of models of great practical importance in the representation of observed time series is the finite moving average process[4]. In this model each value of  $(\varepsilon_{j,t})$  is assumed to arise from the effect of previous values of the independent stochastic component  $(\xi_{j,t})$  rather than the dependent stochastic component  $(\varepsilon_{j,t})$ , thus:

$$\varepsilon_{j,t} = \xi_{j,t} - \sum_{i=1}^q b_i \xi_{j,t-i} \dots\dots\dots (2-42)$$

Where: (q): Order of the model.

$b_i$ : Parameter of the model.

The estimation of the parameter ( $b_i$ ) and the degree of the model were described by Box and Jenkins[4].

**C–Auto Regressive Integrated Moving Average Model [ARIMA(p, d, q)]:**

To achieve greater flexibility in fitting of actual time series, it is some times advantageous to include auto–regressive and moving terms in the model. This model for stationary series may be represented by a mixed auto – regressive moving average [ARMA] (p, q) or ARIMA [p, ·, d] process as follows:

$$\varepsilon_t = \alpha_1 \varepsilon_{t-1} + \alpha_2 \varepsilon_{t-2} + \dots + \alpha_p \varepsilon_{t-p} + \xi_t - b_1 \xi_{t-1} - b_2 \xi_{t-2} \dots - b_q \xi_{t-q} \dots \dots \dots (r-\varepsilon r)$$

Where:

$\varepsilon_t$ : Dependent stochastic component.

$\xi_t$ : Independent stochastic component.

( $\alpha$ ) and ( $b$ ): Parameters of the model.

The model which is capable of representing sequences that are certain types of homogenous non–stationary was developed by Box and Jenkins and obtained by supposing some suitable differences of the process to be stationary.

If the process ( $w_t$ ) is non–stationary in the sense explained above, then it can be converted to a stationary process ( $\varepsilon_t$ ) by taking the suitable difference using:

$$\varepsilon_t = \nabla^d w_t \dots \dots \dots (r-\varepsilon r)$$

Where: ( $\nabla^d$ ) is the (dth) difference of the process ( $w_t$ ). The stationary ( $\varepsilon_t$ ) series is then fitted by equation ( $r-\varepsilon r$ ) and the model designated as (ARIMA) (p, d, q), i.e., the (ARMA) (p, q) model is regarded as a special case of the (ARIMA) model with ( $d = \cdot$ ).

**2.2.2: Multisite Models:**

For the planning, design and operational works of water resources systems, concurrent sequences of flow and water quality data are required at more than one site. This state deals with models which can be used to generate data sets for this purpose. These models should be formulated so that important relationships between the time series are preserved, together with the properties of the individual series [19].

Singlesite models deal with the flow and water quality data at a certain point and consider the serial correlation coefficient only i.e. the correlation exists in time, while they neglect the cross correlation that exists among position. Multisite models consider correlations in both time and space.

The most commonly used Multisite model is limited to the first order auto-regressive model which was initiated in hydrology by Matalas (1967). This model assumed that the series of historical data at each site standardised to zero mean and unit variance after initially removing trend and seasonality.

When (m) represents the number of stations, then:

$\varepsilon_t, \varepsilon_{t-1} = m \times 1$  vector of dependent stochastic component at time (t) and (t-1), respectively.

$\xi_t = m \times 1$  vector of independent stochastic component at time (t). The models takes the form:

$$\varepsilon_t = A\varepsilon_{t-1} + B\xi_t \dots\dots\dots(2-40)$$

Where:

(A) and (B) are two ( m × m ) matrices of parameters.

$$A = M_1 M_0^{-1} \dots\dots\dots(2-41)$$

$$B B^T = M_0 - A M_1^T \dots\dots\dots(2-42)$$

$M_0$ : Lag – zero cross covariance matrix.

$M_1$ : Lag – one cross covariance matrix.

$M_0^{-1}$ : Inverse matrix of ( $M_0$ ).

$M_1^T$ : Transpose matrix of ( $M_1$ ).

The matrix (A) is found directly by substituting the estimated correlation coefficient in the matrix ( $M_1$ ) and ( $M_0$ ), but matrix (B) could be found after obtaining a matrix (C)

$$C = BB^T \dots\dots\dots (\gamma-\varepsilon\lambda)$$

and using the Young and Pisano[ $r^9$ ] method assuming a triangle matrix.

The cross correlation coefficient between two stations is determined by using the following equation:

$$r_k(X, Y) = \frac{\left( (N-K) \sum_{t=1}^{N-K} X_t \cdot Y_{t+k} - \sum_{t=1}^{N-K} X_t \sum_{t=1}^{N-K} Y_{t+k} \right)}{\left[ (N-K) \sum_{t=1}^{N-K} X_t^2 - \left( \sum_{t=1}^{N-K} X_t \right)^2 \right]^{1/2}} \cdot \frac{1}{\left[ (N-K) \sum_{t=1}^{N-K} Y_{t+k}^2 - \left( \sum_{t=1}^{N-K} Y_{t+k} \right)^2 \right]^{1/2}} \dots\dots (\gamma-\varepsilon\eta)$$

Where:

$r_k(X, Y)$ : Lag (k) cross correlation coefficient between stations (X) and (Y).

$X_t$ : Value of the data of station (X) at time (t).

$Y_{t+k}$ : Values of the data of station (Y) at time (t+k).

It is obvious and important point that the models discussed in the above sub-section are only the most commonly used models, where as there exist many other types of models in the literature[ ].

**B – Survey of Available Related Researches:**

Statistical analysis of water quality is a major tool in assessing the state of pollution of rivers, streams, lakes, reservoirs and other water sources. A short review of different types of stochastic models and related researches is presented here in historical sequence.

**Young and Pisano** [39] in (1968) proposed a multisite monthly stream flow model by using Matalas algorithm to preserve the cross correlation between the stations. The data were normalised before starting the analysis using either logarithmic or square root transformation. It was found that such a model was capable of preserving the cross correlation coefficient besides the preservation of means and standard deviations.

**Pentland and Cutherbert** [28] in (1973) presented a multisite daily flow model which was a modification of single site model and was based on generation of monthly flows during dry season and daily flows during flood season. This model had some problems that the sequence of random numbers used in daily generator was not necessarily compatible with the sequence used in monthly generator.

**Huck and Farquhar** [16] in (1974): used the Box and Jenkins techniques for analyzing a time series of water quality data existed as a set of observations that were statistically, sequentially dependent. The overall aim of their analysis was to specify the character of this dependence. The hydrochemical data consist of hourly readings of chloride, temperature, dissolved oxygen, PH. and conductivity. The chloride and dissolved oxygen data were selected for analysis and the authors found that the Box–Jenkins method was successful in modeling the river water quality reviews.

**Ossenbruggen** [27] in (1980): applied probability models derived from a long-term (30) years color record for the Oyster river in Durham. The author formed a method of forecasting raw water color and assigning an alum dose

for treatment of surface waters and used the differencing method to remove linear trend or non-stationary from data series. Three probabilistic models were developed and evaluated: the random walk, log-normal and seasonally AR(1) models. All models were compared for treatment performance. The auto-correlation and partial auto-correlation analysis were used to identify the form of time series models. The results indicated that the two time series models (random walk and seasonally AR(1)) were feasible methods because they led to use of alum without excessive overdosing, in contrast with the log-normal model.

**Al Suhaili** [4] in (1986) studied the stochastic analysis of daily stream flow data of Tigris river for the period extending from (1936-1982) of four stations (Mosul, Fatha, Baghdad and Kut). Trend component was identified and removed using split-sample method. The periodicity was detected by the correlogram technique, then it was analyzed by using Fourier series and removed by harmonic analysis. The dependent stochastic component was found to be well expressed by AR(1) model for each station. Multisite model or (Matalas model) was also used depending on the cross correlation between the four stations. The comparison between generated and observed data was found to be satisfactory.

**Gupta and Chauhan** [13] in (1986) studied the stochastic structure of weekly irrigation requirement of crop. The irrigation requirement time series was assumed to be represented by an additive model with trend, periodic and stochastic as its components. Each component was identified and, if found, removed from the original series. The turning point test and Kendall's rank correlation test were applied for detecting the trend. In the analysis of series, the correlogram technique was used to detect the periodicity, which was then analyzed by Fourier series method. Harmonic analysis was done for identifying the number of significant harmonics. The series was then tested for stationary and dependent part of the stochastic component was found to be

well expressed by the second order auto– regressive model .As a result, the developed model superposes a periodic–deterministic process and a stochastic component. The adequacy of fit was judged by the insignificant correlation and normal distribution of the obtained residuals. The developed periodic–stochastic model may be used for representing the time based structure of the irrigation requirement time series of a paddy crop.

**Lohani and Wang** [२०] in (१९८१) used Box–Jenkins time series analysis for the monthly water quality data in Chung Kang River. The monthly samples which were taken from three stations were analyzed for (१२) parameters and period (१९१६–१९८१). Five years of data (१९१६–१९८०) were used for the basic analysis and the data in the sixth year (१९८१) were used for the comparison of the result forecasted from the time series models. Normalization of data by using square root, logarithmic and power transformation were applied. Auto–correlation and practical auto–correlation were used to define the number of model terms. It was found that the auto–regressive model with order one is the best fit of data and forecasting with seasonal data seemed to perform well when the Box–Jenkin technique was combined with non parametric transformation to remove seasonal cyclic from data.

**Jayawardena and Lai** [११] in (१९८९) applied time series technique to model (२१) years of mean monthly water quality data in the Guangzhou reach of the Pearl river in Southern China. The data of (COD) were measured in two stations for the period (१९६०–१९८०). The basic properties of the water quality data time series were determined. The author defined a time series were determined. The author defined a time series as a combination of four components, trend, periodic, a dependent stochastic and an independent residue components. Trend was detected by using turning point test and Kendall’s rank correlation test, then removed by fitting a regression equation. Periodicity was detected by the auto–correlation and/or spectral analysis and represented by Fourier series. In stochastic component, several (ARMA)

models were investigated which ranged from ARMA (1,0) to ARMA (2,2) to describe the dependent structure of stochastic component. Synthetic water quality data were generated by using the probability distribution of the independent residuals, and forecasting of future water quality data was done using a Box–Jenkins type different model. The comparisons were found to be satisfactory.

**Risley et.al.** [29] in (1993) presented a methodology for forecasting the response of salinity movement in a tidal estuary to seasonal rainfall and fresh water inflows. The forecasting procedure used the linked stochastic and deterministic models which included multisite stochastic rainfall data generation models, a deterministic rainfall–runoff multiple regression model and a one dimensional finite difference salinity intrusion model. Accumulative probability distribution of the maximum salinity flushing distances a long the estuary was developed as a tool for decision–markers. This methodology can be used for long–term seasonal forecasting of salinity intrusion in an estuary under the conditions of seasonal rainfall and fresh water inflows. However, the effects of upstream water withdrawal on downstream flow and salinity are not considered and thus, these forecasting results can not be introduced into a water management model.

**Fernando and Jayawardena** [11] in (1994) described and applied various stages of decomposing and synthesizing a time series to a monthly rainfall data from Sri Lanka for the period (1891–1981). The continuous record was split into two sub–series and the results indicated that the series was non–homogeneity. The turning point test and Kendall’s Rank correlation test were available to detect the trend component, then the trend was removed by fitting a polynomial function. If a periodicity was existed, it could be removed by a Fourier series. The resulting stochastic component were fitted with various (ARMA) models. Generation and forecasting were made by using the

probability distribution and the Box–Jenkins type difference model, respectively, then the results appeared to be satisfactory.

**Ojha and Graham** [26] in (1994) used the technique of auto–regressive process for predicting head loss and filtrate concentration across deep bed media at various times. The problem of evaluating filtrate concentration and head loss values was done by using second order auto–regressive model. The use of this model for short–term predictions of filter performance was clearly feasible. Very good agreement between the predicated and observed values of the filtrate concentration and head loss values resulted by using this model.

**Lall et.al.** [27] in (1996): developed a non–parametric, wet–dry spell model for re–sampling daily rainfall at a site. All marginal, joint and conditional probability densities of interest (dry spell length, wet spell length, precipitation amount and wet spell length given prior to dry spell length) are estimated non–parametrically using at–site data and Kernal probability density estimators. The model was applied to daily rainfall data from Silver Lake Station in Utah (USA) and the performance of the model was evaluated using a number of performance measures. The model reproduced satisfactory the wet day precipitation, wet spell length and dry spell length (Coated by 2001).

**Katsamaki et.al.** [18] in (1998) presented a methodology for data analysis and stochastic modeling of daily municipal solid waste (M.S.W) production rates. The data sets examined were the daily quantities of municipal solid waste for consecutive days and for each day separately. Each sequence of observations was modeled by Box–Jenkins stochastic models as a function of auto–regressive, moving average and seasonal terms. For the overall time series, a seasonal (ARMA) (1,1) was found to be adequate. For the separate day time series, sample auto regressive (AR) models were adequate without inclusion of any seasonal terms. (ACF) and (PACF) were used for the identification of seasonal models and their plots were represented the

confidence limits. Values of these functions within these limits were not significantly different from zero. In general, these models demonstrated statistical fit, and modeling of the trend was satisfactory. Box–Jenkins modeling could be used with success whenever the short–term modeling of (M.S.W) quantities was required. The forecasting ability of these models was compared to simpler statistics and gave satisfactory forecasting depending on the specific day.

**Tarboton et.al.** [34] in (1998): proposed a disaggregation procedure based on non parametric density (NPD) estimation which models adaptively complex relationships between aggregate and disaggregate flows. The primary shortcoming of the (NPD) procedure is that it is data and computationally intensive. For less than (30) years of data, the (NPD) procedure is not expected to disaggregate monthly data better than parametric models. (Cited by 2001).

**Thyer and Kuczera** [35] in (1999): developed a hidden state Markov (HSM) model with Bayesian interface to generate annual rainfall data for Sydney, Australia. The model assumes that the climate is composed of two states, either a dry state (low rainfall year) or a wet state (high rainfall year).

They compared the results from the (HSM) model with those from an AR(1) model and found that the dry spell persistence identified by the (HSM) model procedure higher and more realistic drought risks. (Cited by 2001).

**Mahmood** [36] in (2000) applied Box–Jenkins time series analysis for monthly water quality data which were included ten parameter on the Euphrates River at Kufa for the period (1991–1998). (ACF) and (PACF) were used for the identification seasonal models. Common logarithm transformation was found to be the most suitable one for the water quality data. Stochastic component was found to be well expressed by the (AR) (1) model, AR (2) and ARIMA (1,1,1) model for different parameters. The results were indicated the

suitability of the adopted models and the seasonal component was not existent in these types of observations.

**Al-Husseini [2]** in (2000) applied time series analysis to model eight years of mean monthly hydrochemical data of Shutt Al-Hilla. Trend component was detected and removed by using split-sample method. Power transformation was the suitable method for water quality data. The correlogram technique was used to detect the periodicity, then it was removed by using Fourier series. Dependent stochastic was represented by various stochastic model for each water quality parameter. For forecasting, two stochastic models were developed univariate and multivariate stochastic models. Various models were used to fit stochastic component such as univariate AR(1), MA(1) models for seven parameters. Multivariate stochastic model proved to be good in forecasting hardness. Seven years of data were used for model development, while the model performance was compared with the data for the eighth last year. The comparisons were found to be satisfactory.

**Wang and Nathan [32]** in (2000): developed a daily and monthly mixed (DMM) algorithm for the generation of daily rainfall. Results for the Lake Eppalock Catchment rainfall and for six other sites showed that the (DMM) algorithm reproduced the mean, coefficient of variation and skewness of daily, monthly and annual rainfall. The results were examined for the Lake Eppalock; the algorithm worked well in reproducing the mean, coefficient of variation and skewness of monthly maximum daily rainfall, but not as well for the annual maximum rainfall. For the other six sites, the algorithm worked well in reproducing the mean and coefficient of variation but not as well in reproducing the skewness of the annual maximum daily rainfall (Cited by: Srikanthan and McMahon: 2001).

**Al-Tikriti** [5] in (2001) presented statistical analysis of average weekly water quality data consisting of seven hydrochemical parameters with discharges at two stations (Al-Hindiya and Al-Samawa) for the period (1984–1997). Trend component was detected and removed by using split-sample method. The correlogram technique was used to detect the periodicity, then it was removed by harmonic analysis. Single site auto-regressive model with first order AR(1) model was found convenient for all parameters. Ten years of data (1984–1993) were used for analysis and the remaining four year was used to check the model acceptability. The comparison of the statistical parameters of those records and with generated series was found to be acceptable.

**Grumet et.al.** [12] in (2001) presented multisite records of climate from coasted East Africa which is demonstrated that isotopic tracers preserved with in coral aragonite accurately record intraseasonal to interannual changes in sea surface temperature. They used multisite analysis of sea surface temperature variability along the East Africa coast as recorded in composition of reef corals. The results are generally in agreement with the climate records.

**Wilks** [38] in (2002): presented a method to adjust the parameters of daily time series model for weather generators in away that is consistent with both local climate and probabilistic seasonal forecasts. Both single-station weather generator, and spatial networks of coherently operating weather generators are considered. Only a subset of parameters for individual station models are found to depend appreciably on the seasonal temperature and precipitation outcomes, so that extension to coherent multisite weather generators is straight forward. The results allow stochastic simulation of multiple daily weather series, conditional on seasonal forecasts. Both the science and practice of seasonal forecasting continue to improve, but the forecast products should be used carefully.



## Chapter Four

### Results and Discussions

#### 4.1 Generation of Synthetic Series :

Synthetic data can be generated starting from a sample of the residual series using the appropriate probability distribution[11].

Generation of many sets of data is done with the two models (Single-site AR(1) model and Multi-site (Matalas) (AR(1) model). Statistical tests are applied to check the reliability of the generated sequences at the (99.0%) significant probability level. The general generation procedure can be regarded as reversing the analysis procedure with slight differences, as shown by the following steps :

1- Generation of the independent stochastic component ( $\xi_{i,t}$ ) using normally distributed independent generator available in the software Excel.

2- Generation of the dependent stochastic component ( $\xi_{j,t}$ ) using :

a. Equation (2-30) for single-site AR(1) model.

b. Equation (2-31) for multi-site AR(1) model.

3- Reversing the standardization process,

$$Y_{j,t} = \xi_{j,t} Sd_y + M_y \dots\dots\dots (4-1)$$

4- Calculation of the normalized series.

$$X_{j,t} = M_t + Y_{j,t} Sd_t \dots\dots\dots (4-2)$$

Where: ( $M_t$ ,  $Sd_t$ ) are the periodic means and standard deviations respectively.

5- Applying the inverse power transformation.

$$N_{j,t} = (\lambda X_{j,t} + 1)^{1/\lambda} \dots\dots\dots (4-3)$$

Where : ( $N_{j,t}$ ) is the generated series of year (j) and month (t).

Calibration and verification the model before using it for generation are very important. This will ensure more realistic generated sequences. The comparison between the generated and observed series indicates that there is no need for calibration, Hence, verification is required as shown in tables from (4-1) to (4-16).

































































## 4.2 Verification of the Model

It is important to make sure that those generated sequences are extracted from the same statistical population of the historical series, by verifying the model used in the generation. The basic verification concept of any model is that it generates a sequence of data which preserve most of statistical properties of the historical series.

The properties of the generated series are compared with those of the observed series. The set of data are generated for the flow and water quality parameters of the four stations by each of the models (singlesite AR (1) model, multisite model), the set is of (2) years length, the same length of the observed series which are left for verification (1999-2001).

Tables from (4-1) to (4-16) show the general properties (mean and standard deviation) of the generated monthly series by singlesite model and multisite model and that of the observed one. For checking the model, the generated sequence of data are tested with those of the observed series using (t-test) and (f-test) at 95.0% level of significant as shown in the same tables. The values marked by (\*) sign in these tables are those which failed to pass the (t-test) and (f-test). These indicate the two models are capable of preserving the monthly means and standard deviations for all water quality parameters and discharge.

The percentages of successful test values are shown in tables from (4-17) to (4-32) for the two models, for the two types of water at the four stations. These tables show that the successful percentages indicate the adequacy the singlesite AR(1) and multisite AR(1) model and the values that in the shadow cells which failed to pass the (t-test) and (f-test).

Because two models are used to generate data for all water quality parameters and discharge and for two types of water at four stations, then all the results are plotted against time, therefore some of these plotted selected as shown in figures From (4-1) to (4-16) which represent the monthly mean of the generated and observed data. These figures indicate that the generated data give monthly means slightly different that those of observed data.









**Table (٤-١٧): Percentage of non-significant difference between monthly means of generated by singlesite model and observed series (t-test) for Al-Hindiya station**

		Raw water								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	Q	
		١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%

		Water Supply								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu		
		١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%

**Table (٤-١٨): Percentage of non-significant difference between monthly standard deviations of generated by singlesite model and observed series (f-test) for Al-Hindiya station**

		Raw water								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	Q	
		٦٧%	٩٢%	٩٢%	٩٢%	٩٢%	٨٣%	١٠٠%	١٠٠%	٨٣%

		Water Supply								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu		
		٧٥%	٨٣%	٩٢%	٩٢%	٨٣%	١٠٠%	٩٢%	١٠٠%	

**Table (٤-١٩): Percentage of non-significant difference between monthly means of generated by singlesite model and observed series (t-test) for Al-Hilla station**

		Raw water								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	Q	
		١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%

		Water Supply								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu		
		١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%

**Table (٤-٢٠): Percentage of non-significant difference between monthly standard deviations of generated by single site model and observed series (f-test) for Al-Hilla station**

		Raw water								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	Q	
		٩٢%	٧٥%	٩٢%	١٠٠%	١٠٠%	٨٣%	٨٣%	١٠٠%	٨٣%

		Water Supply								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	TU		
		٩٢%	٩٢%	١٠٠%	٨٣%	٩٢%	٨٣%	٨٣%	١٠٠%	

**Table (٤-٢١): Percentage of non-significant difference between monthly means of generated by singlesite model and observed series (t-test) for Al-Hssien station**

		Raw water								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	Q	
		١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	٩٢%

		Water Supply								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu		
		١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	

**Table (٤-٢٢): Percentage of non-significant difference between monthly standard deviations of generated by singlesite model and observed series (f-test) for Al-Hssien station**

		Raw water								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	Q	
		٧٥%	٣٣%	٨٣%	١٠٠%	٨٣%	٩٢%	٩٢%	٧٥%	١٠٠%

		Water Supply								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu		
		٩٢%	٦٧%	٦٧%	٩٢%	٩٢%	٩٢%	٦٧%	٨٣%	

**Table (٤-٢٣): Percentage of non-significant difference between monthly means of generated by singlesite model and observed series (t-test) for Al-Hashimiya station**

		Raw water								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	Q	
		١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%

		Water Supply							
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	
		١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%

**Table (٤-٢٤): Percentage of non-significant difference between monthly standard deviations of generated by single site model and observed series (f-test) for Al-Hashimiya station**

		Raw water								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	Q	
		٨٣%	٧٥%	٨٣%	١٠٠%	٨٣%	٦٧%	٩٢%	١٠٠%	٩٢%

		Water Supply							
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	
		١٠٠%	٧٥%	٨٣%	١٠٠%	١٠٠%	١٠٠%	٩٢%	١٠٠%

**Table (٤-٢٥): Percentage of non-significant difference between monthly means of generated by multisite model and observed series (t-test) for Al-Hindiya station**

		Raw water							
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	Q
		١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%

		Water Supply							
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	
		١٠٠%	١٠٠%	٨٣%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%

**Table (٤-٢٦): Percentage of non-significant difference between monthly standard deviations of generated by multisite model and observed series (f-test) for Al-Hindiya station**

		Raw water							
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	Q
		٧٥%	٨٣%	٩٢%	٨٣%	٨٣%	١٠٠%	١٠٠%	٩٢%

		Water Supply							
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	
		٧٥%	٨٣%	٩٢%	٧٥%	٩٢%	١٠٠%	١٠٠%	٨٣%

**Table (٤-٢٧): Percentage of non-significant difference between monthly means of generated by multisite model and observed series (t-test) for Al-Hilla station**

		Raw water							
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	Q
		١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%

		Water Supply							
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	
		١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%

**Table (٤-٢٨): Percentage of non-significant difference between monthly standard deviations of generated by multisite model and observed series (f-test) for Al-Hilla station**

		Raw water								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	Q	
		١٠٠%	١٠٠%	١٠٠%	٨٣%	٨٣%	٨٣%	٥٨%	١٠٠%	١٠٠%

		Water Supply								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu		
		١٠٠%	١٠٠%	١٠٠%	٩٢%	٧٥%	١٠٠%	٦٧%	١٠٠%	

**Table (٤-٢٩): Percentage of non-significant difference between monthly means of generated by multisite model and observed series (t-test) for Al-Hssien station**

		Raw water								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	Q	
		١٠٠%	١٠٠%	٩٢%	١٠٠%	١٠٠%	١٠٠%	٣٣%	١٠٠%	١٠٠%

		Water Supply								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu		
		١٠٠%	٩٢%	١٠٠%	١٠٠%	٩٢%	١٠٠%	٨٣%	١٠٠%	

**Table (٤-٣٠): Percentage of non-significant difference between monthly standard deviations of generated by multisite model and observed series (f-test) for Al-Hssien station**

		Raw water								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	Q	
		٧٥%	٧٥%	٧٥%	١٠٠%	٩٢%	١٠٠%	٥٨%	٨٣%	١٠٠%

		Water Supply								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu		
		٩٢%	٨٣%	٩٢%	٩٢%	٧٥%	١٠٠%	٩٢%	٩٢%	

**Table (٤-٣١): Percentage of non-significant difference between monthly means of generated by multisite model and observed series (t-test) for Al-Hashimiya station**

		Raw water								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	Q	
		١٠٠%	١٠٠%	٨٣%	١٠٠%	١٠٠%	١٠٠%	٨%	١٠٠%	٩٢%

		Water Supply							
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	
		١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%	١٠٠%

**Table (٤-٣٢): Percentage of non-significant difference between monthly standard deviations of generated by multisite model and observed series (f-test) for Al-Hashimiya station**

		Raw water								
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	Q	
		٩٢%	٨٣%	٩٢%	٨٣%	٧٥%	٧٥%	٤٢%	٩٢%	٤٢%

		Water Supply							
Percentage of Successful	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	
		١٠٠%	٩٢%	١٠٠%	٥٨%	٩٢%	٧٥%	٨٣%	١٠٠%

## Chapter Five

### Conclusions and Recommendations

#### 5.1 Conclusions:

From this study the following conclusions can be obtained :

- 1- Most of the water quality parameters used in this study are found to have a jump component in all stations which is attributed to the man-made activities upstream these stations. The split sample method is found to be successful to remove this jump.
- 2- All monthly series of water quality parameters and discharge are free from a trend component.
- 3- All hydrochemical parameters and discharge at four stations (raw and pure water) were found to be adequately represented by the first order auto-regressive AR(1) model. The t-test for in significant differences between monthly means of observed and generated series indicates (100%) success.
- 4- The percentages of f-test between monthly variance of observed and generated series show good results for all water quality parameters and discharge (67%) as minimum, except (Ca) in raw water at Al-Hssien station which has a very low percentage (33%).
- 5- The t-test comparison between monthly means of observed and generated series by multisite auto-regressive AR(1) model shows very good results (100%) for most water quality parameters and discharges except (TDS=33%), (TDS = 6%) in raw water Al-Hssien and Al-Hashimiya stations, respectively.

٦- The percentages between monthly variance of observed and generated series by multisite model indicate that the (TDS = ٤٢%, Q = ٤٢%) in raw water at Al-Hashimiya station failed to pass (f-test) and some of these parameters have low values such as (TDS = ٥٨%, TDS = ٦٧%) in raw and pure water at Al-Hilla station, (TDS = ٥٨%) in raw water at Al-Hssien station and (EC = ٥٨%) in pure water at Al-Hashimiya station. All the values or the parameters which failed or have low values indicate that there are different sources of pollutions along the river which dispose their waste into it and change the concentration in the water, therefore the randomness is increased.

#### ٥-٢ Recommendations:

The following recommendations are presented for possible further studies:

- ١- Sampling on shorter time periods (e.g., weekly or daily) should be used in future studies of such water quality parameters to reveal the true nature of such variation and give in sight on the generating process of these time series.
- ٢- Choosing small time interval for turbidity to put an accurate model which describes the fluctuations on it.
- ٣- Multisite-Multivariate model is recommended as a further study to account for the correlation between the stations and water quality parameters.
- ٤- Study the sources of pollutant in between the stations which increase the percentage fail in Matalas model due to cross-correlation effect.





Table (٣-٤): Results of split sample test of original data in Al- Hssien station (raw water-water supply)

Water type	Raw water								
Pollutant	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	Q
t- critical	٢.٢٣	٢.٢٣	٢.٢٣	٢.٢٣	٢.٢٣	٢.٢٣	٢.٢٣	٢.٢٣	٢.٢٣
ε-λt-calcul.	١.٦٤	١.٠٤	٠.٧٨	٠.٢٢	١.٣٧	٠.٣٣	٠.٦١	١.٧٩	١.٧٧
٦-٦t- calcul.	١.٣٨	٢.٠٦	٠.٣٨	١.٤٨	٢.١٢	٠.٥٦	٢.٢٢	٢.٥٨	٣.٥٦
λ-εt- calcul.	٢.٣٦	٢.٩٦	٠.٨٢	٢.٤١	٣.١٧	١.٥١	١.٨٦	٣.٣٣	١.٦٩
ε-λf- critical	٥.٨٩	٥.٨٩	٥.٨٩	٥.٨٩	٥.٨٩	٥.٨٩	٥.٨٩	٥.٨٩	٥.٨٩
٦-٦f- critical	٧.١٥	٧.١٥	٧.١٥	٧.١٥	٧.١٥	٧.١٥	٧.١٥	٧.١٥	٧.١٥
λ-εf- critical	١٤.٦٠	١٤.٦٠	١٤.٦٠	١٤.٦٠	١٤.٦٠	١٤.٦٠	١٤.٦٠	١٤.٦٠	١٤.٦٠
ε-λf-calcul.	٦.٣٧	١.١٦	٣.٦٩	٥.١٠	٢.٧٤	٣.١٨	١.٢٦	١.٨٢	٣.١٣
٦-٦f- calcul.	١.٩٩	١.٣٧	٢.٧٢	١.٤٧	١.٤٧	٢.١٥	١٣.٠٦	١.٣٠	٥.٤٨
λ-εf- calcul.	٣.١٣	١.٧٥	١.٥٢	١.٥٢	١.٧٤	٢.٦٤	١٨.٣٢	٢.٠٤	٢٥.٨٧
f-test	ε-λ	Homog.	Homog.	Homog.	Homog.	Homog.	λ-ε	Homog.	λ-ε

Water type	Water supply								
Pollutant	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	
t- critical	٢.٢٣	٢.٢٣	٢.٢٣	٢.٢٣	٢.٢٣	٢.٢٣	٢.٢٣	٢.٢٣	٢.٢٣
ε-λt-calcul.	١.٢٤	١.٢٧	٠.٣٦	٠.٤٨	١.٢٠	٠.٢٦	٠.٥٣	٠.٠١	
٦-٦t- calcul.	١.٤٧	٢.٦٧	٠.٥٤	٢.٠١	٢.٣٧	٠.٩١	٣.٣٣	٠.٨٧	
λ-εt- calcul.	٢.٥٣	٣.٤٧	٠.٨٩	٣.٠٩	٣.٦٢	٢.٥٣	٢.٨٧	١.٠١	
ε-λf- critical	٥.٨٩	٥.٨٩	٥.٨٩	٥.٨٩	٥.٨٩	٥.٨٩	٥.٨٩	٥.٨٩	٥.٨٩
٦-٦f- critical	٧.١٥	٧.١٥	٧.١٥	٧.١٥	٧.١٥	٧.١٥	٧.١٥	٧.١٥	٧.١٥
λ-εf- critical	١٤.٦٠	١٤.٦٠	١٤.٦٠	١٤.٦٠	١٤.٦٠	١٤.٦٠	١٤.٦٠	١٤.٦٠	١٤.٦٠
ε-λf-calcul.	٧.١٢	١.٤٦	٥.٩٣	١.٤٦	٣.٤٧	٣.١١	١.١٣	١.٧٧	
٦-٦f- calcul	١.٧٦	١.٣٨	٢.٣٧	١.١٠	١.٣٧	١.١٥	٥.٥٦	١٤.٠٢	
λ-εf- calcul	٢.٧٦	١.٥١	١.٢٦	١.٢١	١.٢٨	٣.٨٣	١٥.٧٣	٢٥.٨١	
f-test	ε-λ	Homog.	ε-λ	Homog.	Homog.	Homog.	λ-ε	λ-ε	



Table (3-9): Results of split sample test of original data in Al- Hashimiya station (raw water-water supply)

Water type	Raw water								
Pollutant	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	Q
t- critical	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23
ε-λt-calcul.	0.77	0.42	0.57	0.75	2.03	1.91	1.39	0.71	2.43
γ-γt- calcul.	2.07	2.14	0.28	2.40	2.16	1.60	3.96	3.43	4.03
λ-εt- calcul.	2.03	4.06	0.92	3.60	3.69	1.63	3.40	2.04	1.09
ε-λf- critical	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
γ-γf- critical	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10
λ-εf- critical	14.60	14.60	14.60	14.60	14.60	14.60	14.60	14.60	14.60
ε-λf-calcul.	1.68	4.17	8.96	1.06	1.47	3.44	4.13	1.18	4.40
γ-γf- calcul.	1.00	2.14	1.84	1.42	1.41	2.02	2.19	0.20	2.32
λ-εf- calcul.	1.74	2.03	1.12	1.40	1.08	100.79	3.20	0.67	2.18
f-test	Homog	Homog	ε-λ	Homog	Homog	λ-ε	Homog	Homog	Homog

Water type	Water supply								
Pollutant	Alk	Ca	Cl	EC	Ha	Mg	TDS	Tu	
t- critical	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23
ε-λt-calcul.	0.39	2.68	1.84	1.48	1.04	0.90	4.01	1.66	
γ-γt- calcul.	2.06	2.06	0.39	2.92	2.32	0.96	0.14	0.32	
λ-εt- calcul.	2.21	4.09	1.30	4.11	4.00	1.61	4.67	0.16	
ε-λf- critical	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	
γ-γf- critical	7.10	7.10	7.10	7.10	7.10	7.10	7.10	7.10	
λ-εf- critical	14.60	14.60	14.60	14.60	14.60	14.60	14.60	14.60	
ε-λf-calcul.	2.42	1.40	1.33	2.46	7.24	1.37	1.98	119.03	
γ-γf- calcul	2.13	3.68	1.40	1.79	1.77	3.80	1.09	17.31	
λ-εf- calcul	4.33	3.27	1.17	1.08	1.36	10.74	1.60	22.87	
f-test	Homog	Homog	Homog	Homog	ε-λ	λ-ε	Homog	ε-λ	



**Table (۳-۶): Coefficients required for removing non-homogeneity for Al-Hindiya station (raw water-water supply)**

Water Quality Parameter	Reg. Coef. of Mean		Reg. Coef. of Sd		Mean-۲/M	Sd-۲/M
	A	B	A	B		
Ca	۱۷۵.۱۵	-۷.۰۴	۱۷.۹۱	۰.۳۹	۸۸.۰۴	۳۱.۲۹
EC	۱۳۸۴.۷۵	-۲۵.۱۲	۲۳۵.۵۸	-۱۲.۵۳	۱۰.۶۶.۸۳	۱۲۱.۹۲
Ha	۷۱۱.۱۴	-۲۵.۱۶	۷۵.۷۷	-۲.۶۰	۴۰.۱.۶۳	۸۷.۲۵
Mg	۶۳.۱۵	-۱.۴۷	۲۱.۷۱	-۱.۱۴	۴۶.۵۷	۵.۵۴
TDS	۹۷۳.۱۱	-۲۰.۲۶	۸۳.۳۸	-۰.۹۰	۷۳۲.۳۵	۶۵.۳۷
Tu	۱۶.۷۶	۰.۷۵	۵.۸۸	۰.۳۹	۲۴.۴۴	۴.۱۱
Q	۱۷۴.۷۵	۲.۸۲	۱۸.۸۴	۰.۳۷	۲۰.۳.۳۰	۵.۷۸

Water Quality Parameter	Reg. Coef. of Mean		Reg. Coef. of Sd		Mean-۲/M	Sd-۲/M
	A	B	A	B		
Ca	۱۸۲.۷۸	-۸.۱۸	۳۲.۸۵	-۱.۳۰	۸۴.۲۵	۲۹.۹۷
EC	۱۴۲۵.۸۸	-۳۴.۰۰	۱۵۴.۴۱	-۴.۶۱	۱۰۰۵.۶۷	۱۱۹.۱۱
Ha	۶۹۷.۳۹	-۲۵.۱۵	۹۶.۹۷	-۵.۰۹	۳۸۸.۷۱	۹۰.۳۲
TDS	۱۰۳۲.۱۵	-۲۹.۹۶	۹۰.۳۹	-۲.۱۷	۶۸۹.۴۲	۷۰.۶۹
Tu	۴.۶۳	۲.۸۲	۱.۹۱	-۰.۰۲	۵.۶۳	۰.۲۹

**Table (۳-۷): Coefficients required for removing non-homogeneity for Al-Hilla station (raw water-water supply)**

Water Quality Parameter	Reg. Coef. of Mean		Reg. Coef. of Sd		Mean-۲/M	Sd-۲/M
	A	B	A	B		
Alk	۱۰۷.۴۵	۲.۳۲	۳۲.۳۰	-۱.۶۶	۱۳۶.۲۱	۱۴.۵۸
Ca	۱۶۹.۶۴	-۶.۴۹	۴۴.۳۱	-۲.۵۱	۸۴.۰۶	۳۵.۴۶
EC	۱۳۸۶.۴۰	-۲۵.۳۰	۲۲۹.۴۳	-۱۲.۷۰	۱۰۴۷.۳۳	۱۰۳.۷۹
Ha	۷۰۹.۵۴	-۱۶.۱۳	۱۷۷.۸۶	-۱۳.۷۱	۳۹۰.۳۵	۹۴.۴۴
TDS	۹۸۶.۱۴	-۲۴.۸۹	۲۱۸.۲۲	-۱۳.۵۵	۷۰۳.۵۲	۶۱.۷۱
Q	۱۴۰.۸۱	۲.۲۱	۲۰.۱۱	۰.۹۱	۱۶۳.۷۲	۳.۴۲

Water Quality Parameter	Reg. Coef. of Mean		Reg. Coef. of Sd		Mean-۲/M	Sd-۲/M
	A	B	A	B		
Alk	۱۰۳.۷۱	۱.۸۶	۳۲.۴۳	-۱.۵۱	۱۲۸.۸۲	۱۲.۳۹
Ca	۱۷۴.۴۵	-۷.۴۰	۵۴.۹۸	-۳.۸۸	۸۰.۹۴	۳۳.۳۶
EC	۱۴۱۴.۷۲	-۳۳.۰۹	۲۳۸.۰۵	-۱۴.۷۲	۹۷۹.۷۳	۱۰۹.۷۱
Ha	۶۸۱.۶۸	-۲۵.۵۷	۱۵۴.۴۸	-۸.۹۱	۳۶۰.۹۰	۷۱.۹۱
Mg	۵۷.۷۳	-۱.۲۶	۱۴.۴۵	-۰.۵۱	۴۳.۹۷	۴.۰۳
TDS	۹۶۴.۵۵	-۲۰.۵۹	۱۵۴.۷۴	-۶.۶۰	۷۲۳.۲۱	۲۳.۷۳
Tu	۸.۷۲	-۰.۱۲	۲.۸۰	۰.۰۱	۳.۶۴	۱.۹۳



**Table (3-8): Coefficients required for removing non-homogeneity for Al-Hssien station (raw water-water supply)**

Water Quality Parameter	Reg. Coef. of Mean		Reg. Coef. of Sd		Mean- $\nu$ /M	Sd- $\nu$ /M
	A	B	A	B		
Alk	117.02	1.26	31.89	-1.82	144.70	12.02
Ca	179.09	-0.77	37.80	-1.00	99.06	32.70
EC	1396.71	-17.98	146.28	-0.08	1163.83	100.90
Ha	668.10	-17.38	117.03	-3.71	449.88	96.99
TDS	938.13	-8.07	114.64	-0.44	837.02	17.64
Tu	20.68	1.12	13.01	-0.49	33.60	3.19
Q	121.22	2.21	16.33	0.98	139.20	2.92

Water Quality Parameter	Reg. Coef. of Mean		Reg. Coef. of Sd		Mean- $\nu$ /M	Sd- $\nu$ /M
	A	B	A	B		
Alk	110.76	1.04	33.23	-1.77	142.10	13.87
Ca	178.63	-7.11	38.72	-1.62	90.60	29.79
Cl	278.90	-1.60	78.89	-2.06	08.78	29.66
EC	1408.78	-24.80	141.70	-1.97	1103.20	106.08
Ha	670.71	-18.36	104.00	-1.03	443.44	79.26
Mg	00.67	-0.01	14.26	-0.21	40.90	3.63
TDS	964.08	-14.46	107.19	-0.33	812.99	33.12
Tu	7.94	0.12	3.43	-0.11	7.48	2.30

**Table (3-9): Coefficients required for removing non-homogeneity for Al-Hashimiya station (raw water-water supply)**

Water Quality Parameter	Reg. Coef. of Mean		Reg. Coef. of Sd		Mean- $\nu$ /M	Sd- $\nu$ /M
	A	B	A	B		
Alk	101.07	3.03	40.02	-2.40	136.39	20.16
Ca	173.80	-6.03	26.03	-0.60	91.94	29.03
Cl	281.81	-0.43	73.72	-1.88	07.83	37.30
EC	1400.40	-24.08	120.26	2.10	1100.33	110.02
Ha	663.00	-19.22	79.74	-3.76	411.71	86.02
Mg	06.02	-0.03	18.60	-0.84	47.71	1.00
TDS	989.06	-16.37	80.13	-1.70	827.00	38.06
Tu	19.83	1.29	9.38	0.11	32.10	2.23
Q	106.74	1.33	13.73	0.92	121.70	6.01

Water Quality Parameter	Reg. Coef. of Mean		Reg. Coef. of Sd		Mean- $\nu$ /M	Sd- $\nu$ /M
	A	B	A	B		
Ca	100.76	2.09	48.64	-3.07	82.46	31.78
EC	1440.64	-32.06	129.94	-2.10	1030.00	124.81
Ha	670.79	-21.97	70.93	-3.49	391.80	91.10
Mg	03.06	-0.33	12.84	-0.29	44.90	3.33
TDS	1009.70	-29.41	101.70	-2.09	770.32	73.30
Tu	7.68	0.29	2.32	0.00	3.00	1.28



**Table (3-10): Results of split sample test after removing jump for Al- Hindiya station (raw water-water supply)**

Water type	Pollutant	n <sub>1</sub>	n <sub>2</sub>	t-calc./M	t-critical	M-test	F-calc.	F- critical	F- Test
Raw water	Ca	8	4	0.19	2.23	HOMOG.	1.27	14.60	HOMOG.
	EC	8	4	0.04		HOMOG.	1.05	14.60	HOMOG.
	Ha	8	4	0.10		HOMOG.	1.12	14.60	HOMOG.
	Mg	6	6	0.04		HOMOG.	1.05	7.10	HOMOG.
	TDS	8	4	0.03		HOMOG.	1.03	14.60	HOMOG.
	Tu	6	6	0.03		HOMOG.	1.03	7.10	HOMOG.
	Q	6	6	0.00		HOMOG.	1.00	7.10	HOMOG.

Water type	Pollutant	n <sub>1</sub>	n <sub>2</sub>	t-calc./M	t- critical	M-test	F-calc.	F- critical	F- Test
Water supply	Ca	8	4	0.17	2.23	HOMOG.	1.24	14.60	HOMOG.
	EC	8	4	0.06		HOMOG.	1.07	14.60	HOMOG.
	Ha	8	4	0.16		HOMOG.	1.23	14.60	HOMOG.
	TDS	8	4	0.03		HOMOG.	1.04	14.60	HOMOG.
	Tu	8	4	0.01		HOMOG.	1.01	14.60	HOMOG.

**Table (٣-١١): Results of split sample test after removing jump for Al- Hilla station (raw water-water supply)**

Water type	Pollutant	n <sub>١</sub>	n <sub>٢</sub>	t-calc./M	t- critical	M-test	F-calc.	F- critical	F- Test
Raw water	Alk	٦	٦	٠.٠٥	٢.٢٣	HOMOG.	١.٠٧	٧.١٥	HOMOG.
	Ca	٨	٤	٠.٢٩		HOMOG.	١.٤٥	١٤.٦٠	HOMOG.
	EC	٨	٤	٠.٠٥		HOMOG.	١.٠٧	١٤.٦٠	HOMOG.
	Ha	٨	٤	٠.١٤		HOMOG.	١.١٩	١٤.٦٠	HOMOG.
	TDS	٨	٤	٠.٠٢		HOMOG.	١.٠٢	١٤.٦٠	HOMOG.
	Q	٦	٦	٠.٠٠		HOMOG.	١.٠٠	٧.١٥	HOMOG.

Water type	Pollutant	n <sub>١</sub>	n <sub>٢</sub>	t-calc./M	t-tabul.	M-test	F-calc.	F-tabul.	F- Test
Water supply	ALK	٦	٦	٠.٠٦	٢.٢٣	HOMOG.	١.٠٧	٧.١٥	HOMOG.
	CA	٨	٤	٠.٢٦		HOMOG.	١.٤٠	١٤.٦٠	HOMOG.
	EC	٨	٤	٠.٠٧		HOMOG.	١.٠٩	١٤.٦٠	HOMOG.
	HA	٨	٤	٠.١١		HOMOG.	١.١٤	١٤.٦٠	HOMOG.
	MG	٦	٦	٠.٠٣		HOMOG.	١.٠٣	٧.١٥	HOMOG.
	TDS	٨	٤	٠.٠١		HOMOG.	١.٠١	١٤.٦٠	HOMOG.
	TU	٤	٨	٠.٠٤		HOMOG.	١.٠٦	٥.٨٩	HOMOG.

**Table (٣-١٢): Results of split sample test after removing jump for Al- Hssien station (raw water-water supply)**

Water type	Pollutant	n <sub>١</sub>	n <sub>٢</sub>	t-calc./M	t- critical	M-test	F-calc.	F- critical	F- Test
Raw water	Alk	٨	٤	٠.٠٦	٢.٢٣	HOMOG.	١.٠٧	١٤.٦٠	HOMOG.
	Ca	٨	٤	٠.١٢		HOMOG.	١.١٦	١٤.٦٠	HOMOG.
	EC	٨	٤	٠.٠٢		HOMOG.	١.٠٣	١٤.٦٠	HOMOG.
	Ha	٨	٤	٠.٠٨		HOMOG.	١.١٠	١٤.٦٠	HOMOG.
	TDS	٨	٤	٠.٠٠		HOMOG.	١.٠٠	١٤.٦٠	HOMOG.
	Tu	٨	٤	٠.٠١		HOMOG.	١.٠١	١٤.٦٠	HOMOG.
	Q	٦	٦	٠.٠٠		HOMOG.	١.٠٠	٧.١٥	HOMOG.

Water type	Pollutant	n <sub>١</sub>	n <sub>٢</sub>	t-calc./M	t- critical	M-test	F-calc.	F- critical	F- Test
Water supply	Alk	٨	٤	٠.٠٧	٢.٢٣	HOMOG.	١.٠٨	١٤.٦٠	HOMOG.
	Ca	٨	٤	٠.٠٩		HOMOG.	١.١٢	١٤.٦٠	HOMOG.
	Cl	٤	٨	٠.٠٨		HOMOG.	١.١٠	٥.٨٩	HOMOG.
	EC	٨	٤	٠.٠٣		HOMOG.	١.٠٤	١٤.٦٠	HOMOG.
	Ha	٨	٤	٠.٠٥		HOMOG.	١.٠٧	١٤.٦٠	HOMOG.
	Mg	٨	٤	٠.٠٢		HOMOG.	١.٠٣	١٤.٦٠	HOMOG.
	TDS	٦	٦	٠.٠١		HOMOG.	١.٠١	٧.١٥	HOMOG.
	Tu	٨	٤	٠.٠٤		HOMOG.	١.٠٤	١٤.٦٠	HOMOG.

**Table (٣-١٣): Results of split sample test after removing jump for Al- Hashimiya station (raw water-water supply)**

Water type	Pollutant	n <sub>١</sub>	n <sub>٢</sub>	t-calc./M	t- critical	M-test	F-calc.	F- critical	F- Test
Raw water	Alk	٦	٦	٠.١٥	٢.٢٣	HOMOG.	١.٢	١٤.٦٠	HOMOG.
	Ca	٨	٤	٠.١٧		HOMOG.	١.٢٣	١٤.٦٠	HOMOG.
	EC	٨	٤	٠.٠٢		HOMOG.	١.٠٣	١٤.٦٠	HOMOG.
	Ha	٨	٤	٠.١٨		HOMOG.	١.٢٥	١٤.٦٠	HOMOG.
	Mg	٨	٤	٠.٠٠		HOMOG.	١.٠١	١٤.٦٠	HOMOG.
	TDS	٦	٦	٠.٠١		HOMOG.	١.٠١	٧.١٥	HOMOG.
	Tu	٦	٦	٠.٠٢		HOMOG.	١.٠٣	٧.١٥	HOMOG.
	Q	٦	٦	٠.٠١		HOMOG.	١.٠١	٧.١٥	HOMOG.

Water type	Pollutant	n <sub>١</sub>	n <sub>٢</sub>	t-calc./M	t- critical	M-test	F-calc.	F- critical	F- Test
Water supply	Ca	٨	٤	٠.١٧	٢.٢٣	HOMOG.	١.٢٤	١٤.٦٠	HOMOG.
	EC	٨	٤	٠.٠٤		HOMOG.	١.٠٦	١٤.٦٠	HOMOG.
	Ha	٨	٤	٠.٢٠		HOMOG.	١.٢٨	١٤.٦٠	HOMOG.
	Mg	٨	٤	٠.٠٣		HOMOG.	١.٠٣	١٤.٦٠	HOMOG.
	TDS	٦	٦	٠.٠٢		HOMOG.	١.٠٢	٧.١٥	HOMOG.
	Tu	٤	٨	٠.١٠		HOMOG.	١.١٣	١٤.٦٠	HOMOG.

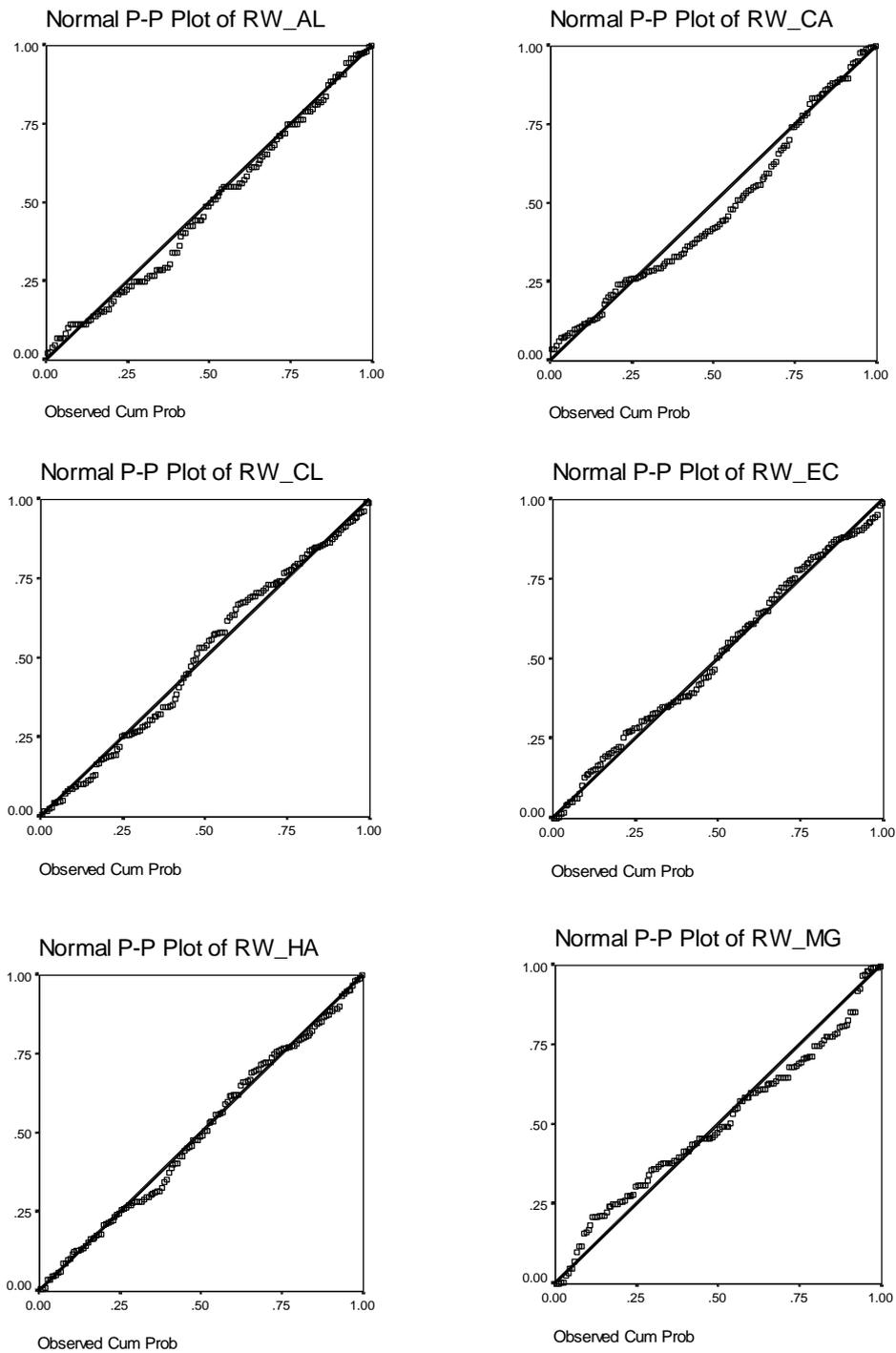




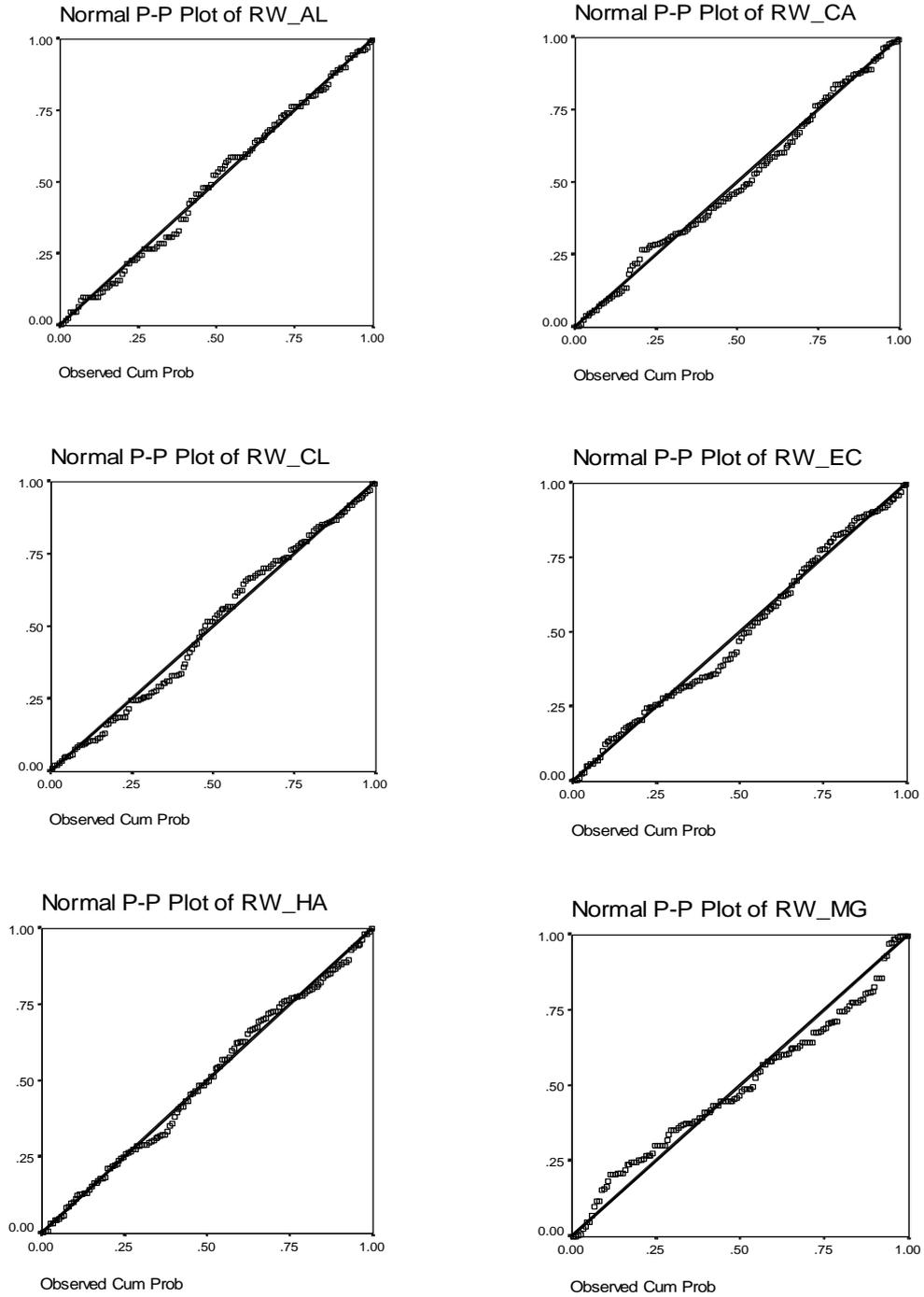




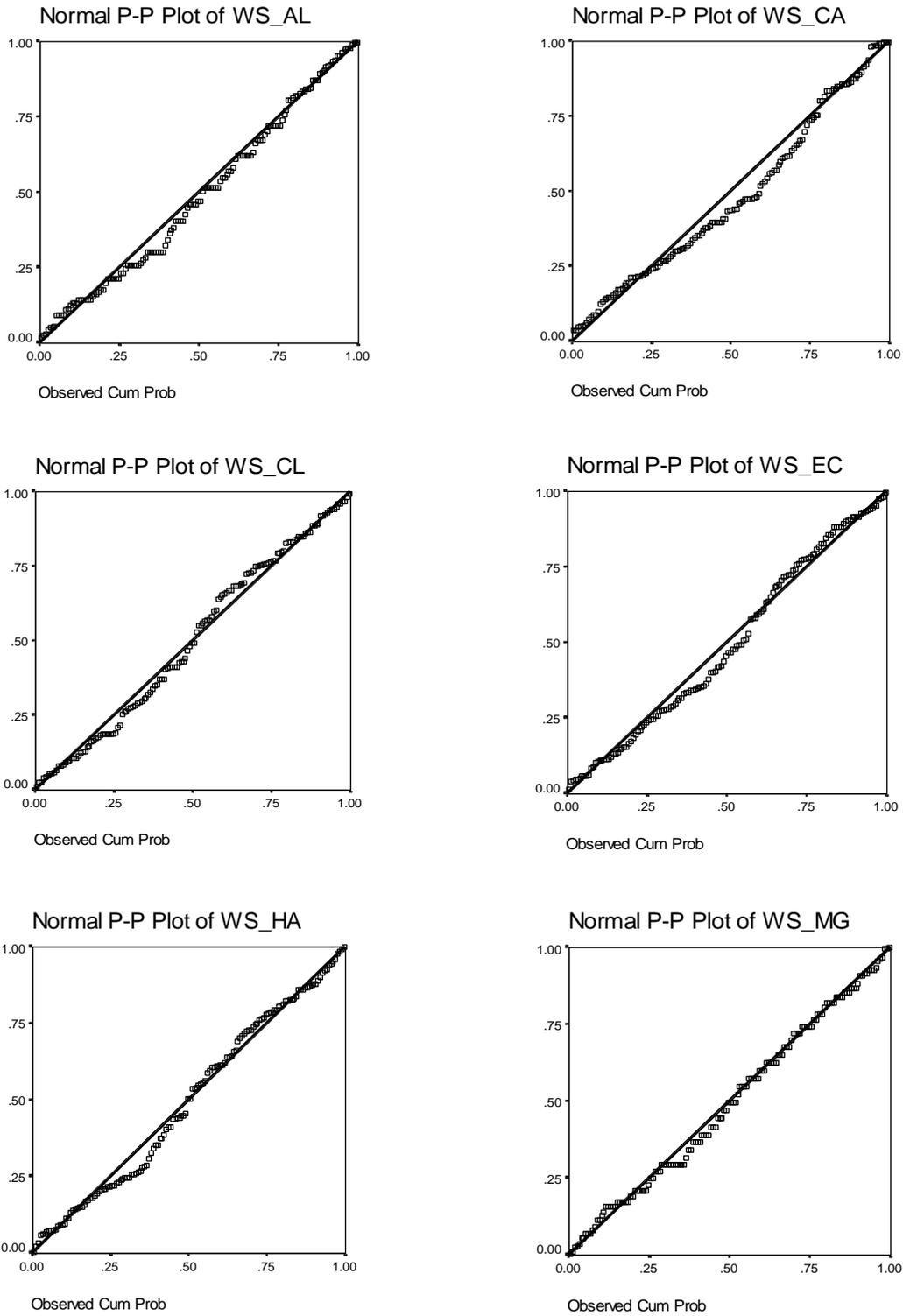




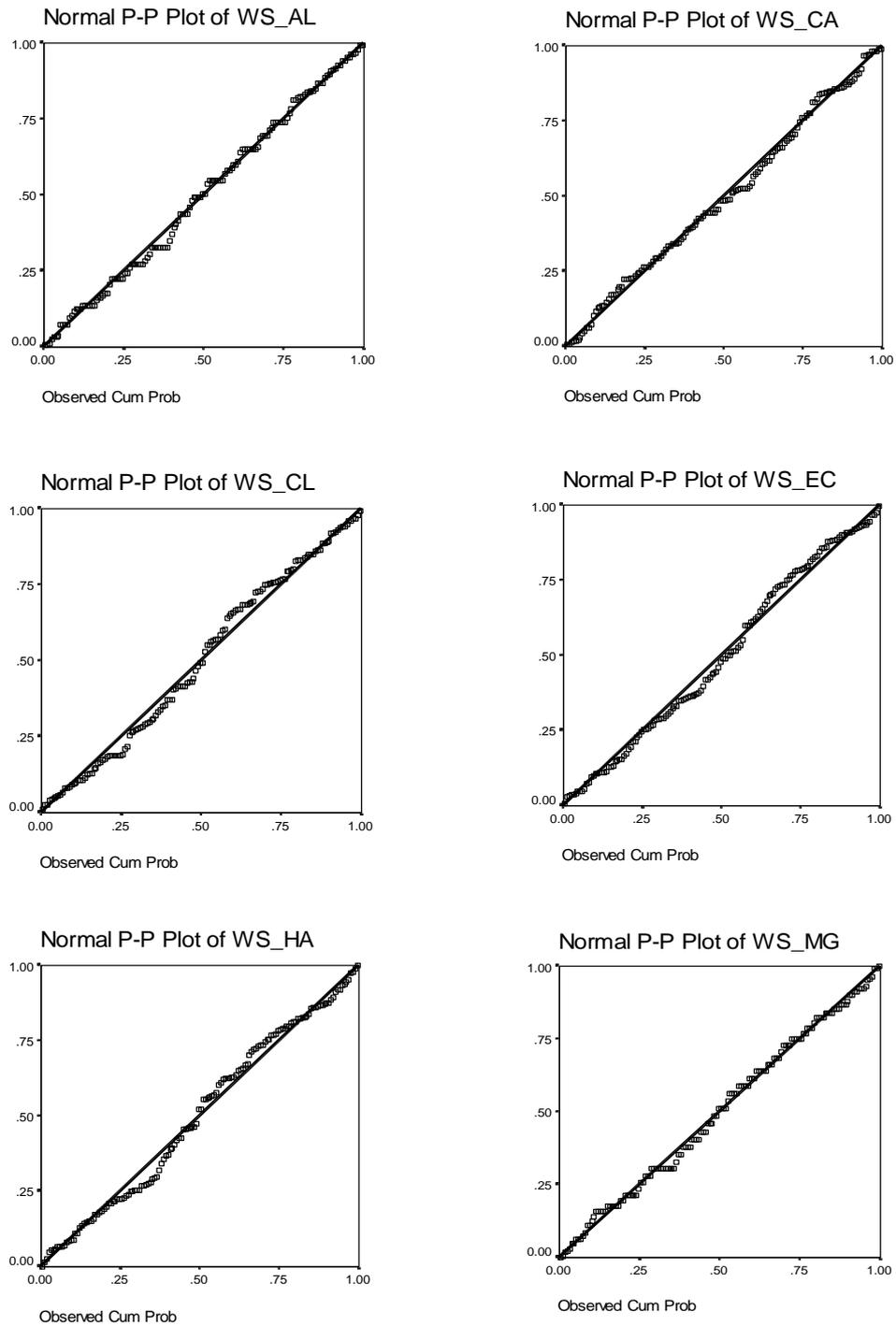
**Fig. (3-9): Probability plots of homogeneous data for Al-Hindiya station (raw water) (1987-1998)**



**Fig. (3-10):** Probability plots of normalized data for Al-Hindiya station (raw water (1987-1998))

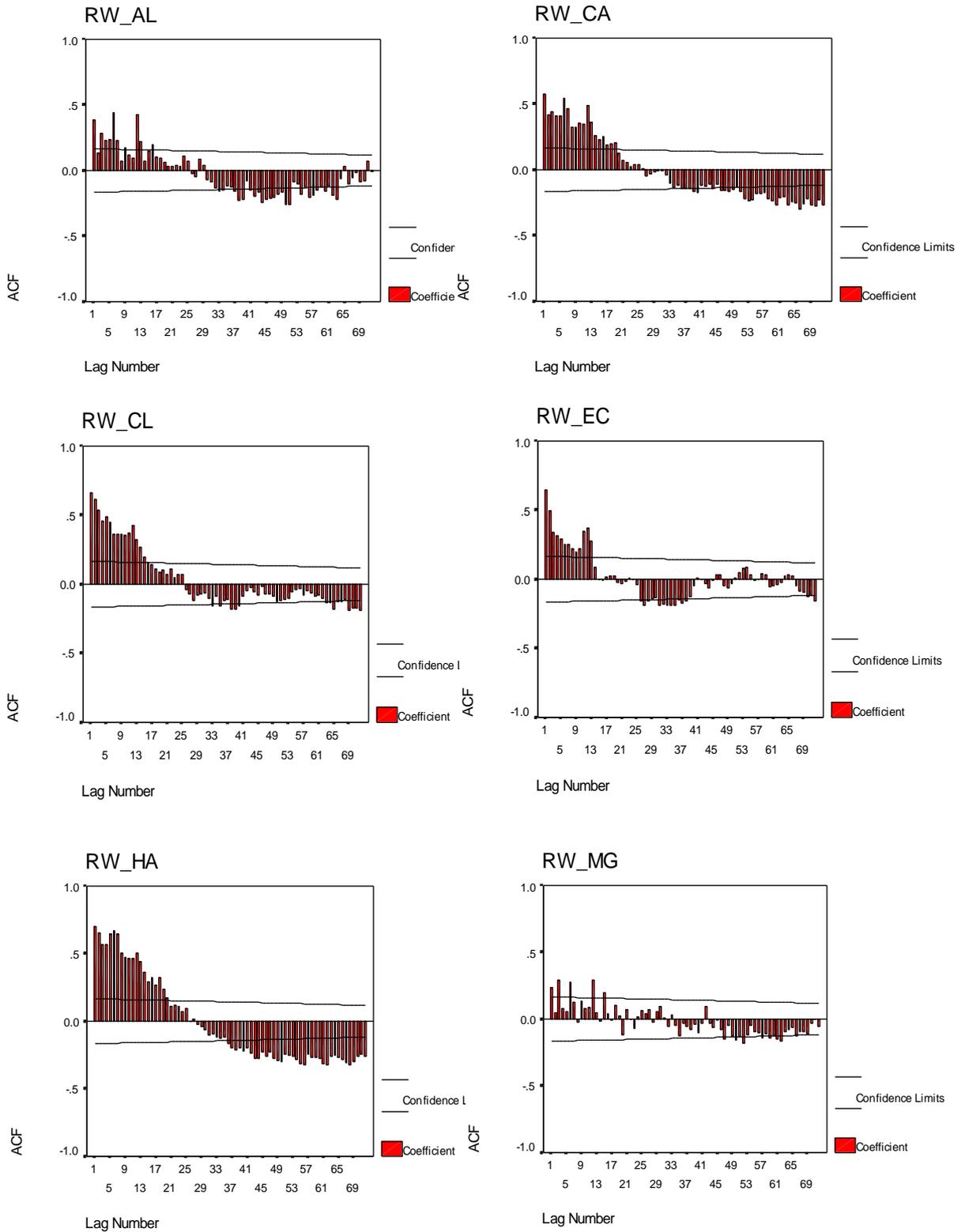


**Fig. (3-11): Probability plots of homogeneous data for Al-Hindiya station (water supply) (1987-1998)**

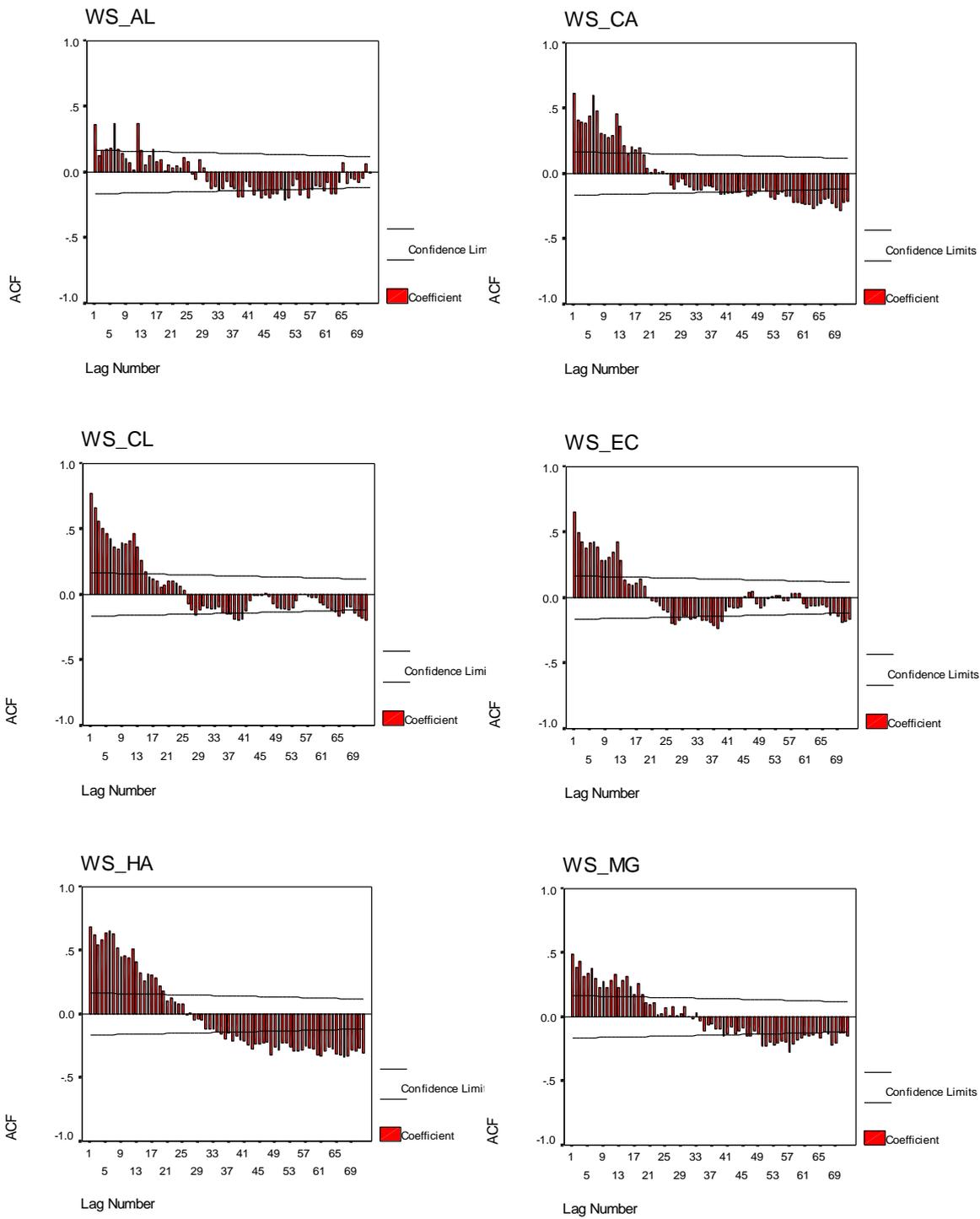


**Fig. (3-12): Probability plots of normalized data for Al-Hindiya station (water supply) (1987-1998)**





**Fig. (٣-١٣): Correlogram plots of normalized data for Al-Hindiya station (raw water) (١٩٨٧-١٩٩٨)**



**Fig. (3-14): Correlogram of normalized data for Al-Hindiya station (water supply) (1987-1998)**

































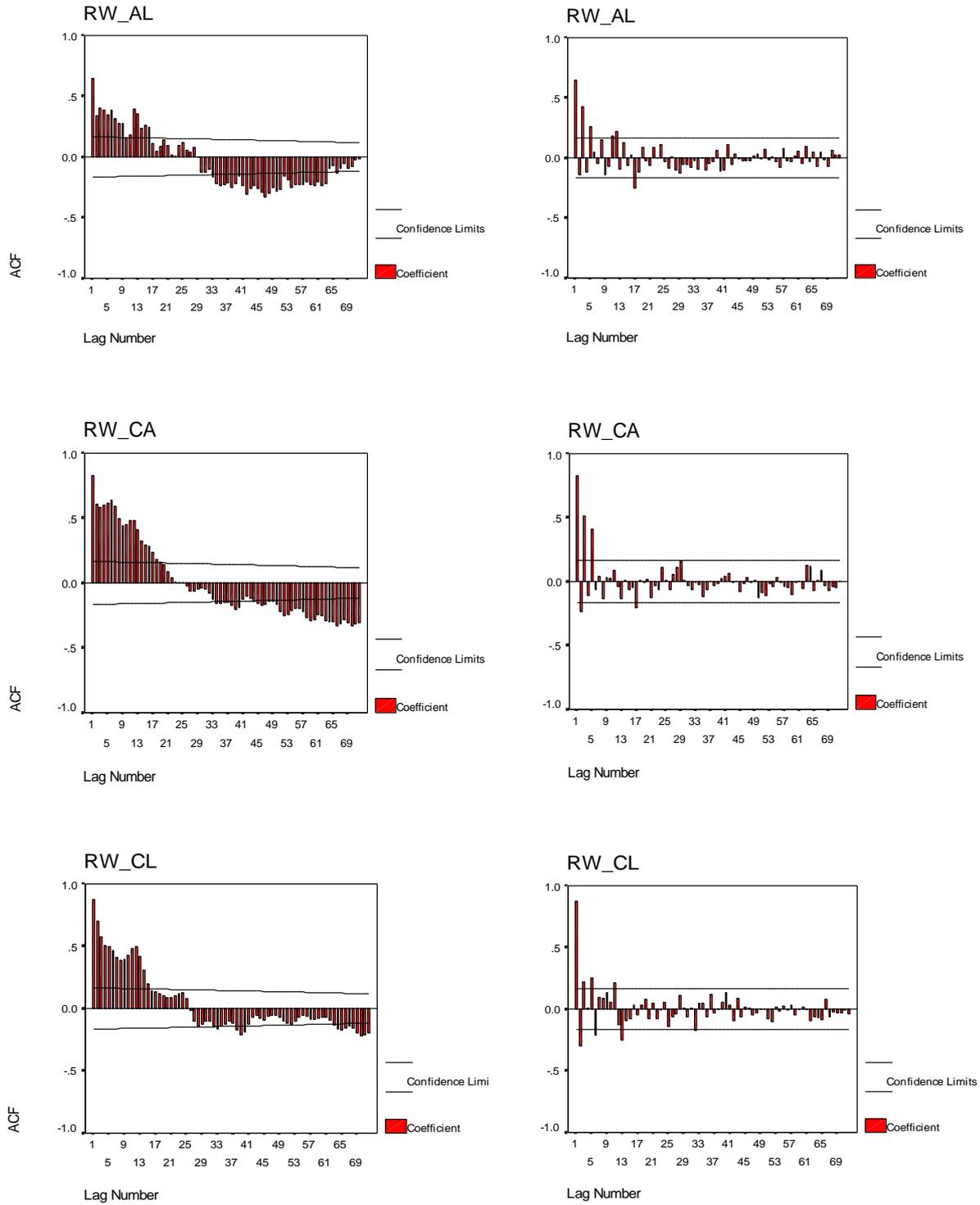




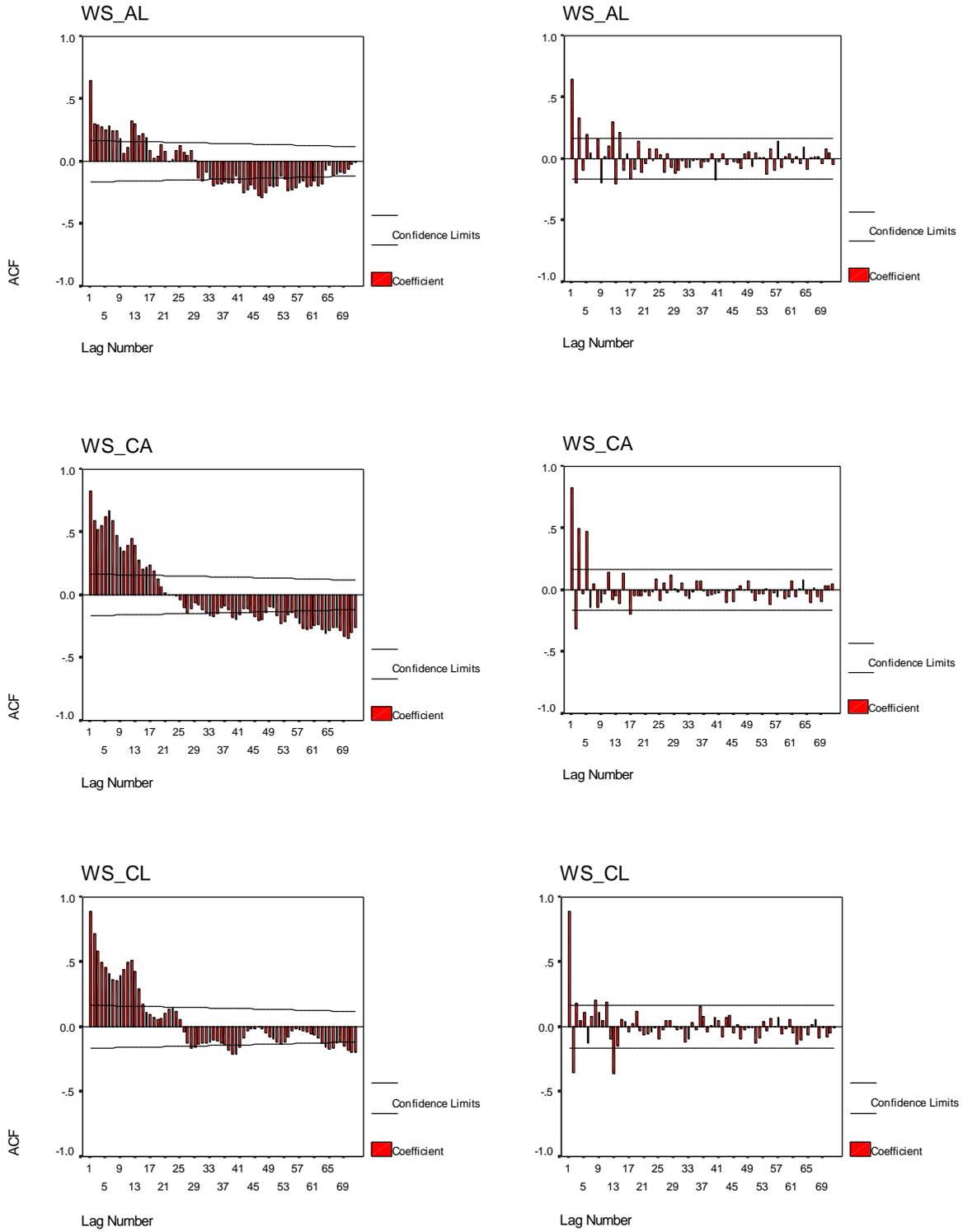








**Fig. (٣-٢١): Correlogram for the independent stochastic component of the series at Al-Hindiya station (raw water)**



**Fig. (3-22): Correlogram for the independent stochastic component of the series at Al-Hindiya station (water supply)**

Table (3-23): Effect of power transformation on the first four moments of each series in Al-Hindiya station (raw water-water supply)

Pollutant	Before transformation				After transformation			
	Mean	Sd	C <sub>S</sub>	C <sub>k</sub>	Mean	Sd	C <sub>S</sub>	C <sub>k</sub>
Alk	120.04	23.27	-0.162	-0.698	12.0170	0.6089	0.0000	-0.29
Ca	90.00	39.49	-0.373	-1.370	19.90417	1.3018	0.0000	-0.00
Cl	268.00	71.84	-0.004	-0.982	643.2020	78.0049	0.0000	-0.64
EC	1080.60	98.70	-0.088	-1.343	1297.79.72 1	93823.30	0.0000	-0.09
Ha	428.02	114.90	-0.201	-1.260	216.8767	12.4290	0.0000	0.17
Mg	47.16	4.69	1.040	0.464	66.08767	0.4791	0.0000	1.99
TDS	740.60	61.00	0.280	-0.690	28.3882	142.2002	0.0000	-0.69
Tu	24.20	2.96	1.042	3.749	9.0370	1.0006	0.0000	3.00
Q	203.00	3.90	1.061	2.494	119.0170	4.6900	0.0000	1.98

Pollutant	Before transformation				After transformation			
	Mean	Sd	C <sub>S</sub>	C <sub>k</sub>	Mean	Sd	C <sub>S</sub>	C <sub>k</sub>
Alk	118.74	21.26	-0.20	-0.034	16.40833	0.9242	0.0000	-0.29
Ca	90.63	30.69	-0.336	-1.327	13.99667	0.8096	0.0000	-0.01
Cl	209.46	72.21	-0.010	-0.902	249.6770	20.8310	0.0000	-0.76
EC	1028.87	126.64	0.098	-1.382	27.19	0.4332	0.0000	-0.69
Ha	416.00	106.44	-0.211	-1.603	98.09	3.2481	0.0000	-0.11
Mg	01.10	10.08	-0.040	-1.213	24.270	1.0291	0.0000	0.43
TDS	699.02	63.78	-0.487	-1.037	209.000	9.1938	0.0000	-0.82
Tu	0.60	0.18	-0.097	1.432	0.239167	0.3879	0.0000	2.74

Table (3-24): Effect of power transformation on the first four moments of each series in Al-Hilla station (raw water-water supply)

Pollutant	Before transformation				After transformation			
	Mean	Sd	C <sub>S</sub>	C <sub>k</sub>	Mean	Sd	C <sub>S</sub>	C <sub>k</sub>
Alk	133.80	13.14	0.913	1.109	1.883333	0.0601	0.0000	0.97
Ca	90.44	37.24	-0.014	-1.861	27.76833	2.8017	0.0000	-0.22
Cl	206.19	80.02	0.277	-0.921	709.9117	87.2267	0.0000	-0.99
EC	1069.94	99.37	-0.060	-1.633	321720.90	21737.41	0.0000	0.03
Ha	413.43	87.10	0.024	-1.743	106.90	94.1364	0.0000	-0.63
Mg	43.63	3.13	-0.067	-0.902	26.60	2.0201	0.0000	1.16
TDS	708.12	39.30	0.992	0.682	13090069027.0	190000000000	0.0000	-0.01
Tu	28.30	2.40	0.324	0.648	3.82	0.1880	0.0000	1.06
Q	163.06	2.43	1.038	2.061	2043.94	269.4331	0.0000	2.03

Pollutant	Before transformation				After transformation			
	Mean	Sd	C <sub>S</sub>	C <sub>k</sub>	Mean	Sd	C <sub>S</sub>	C <sub>k</sub>
Alk	126.68	11.86	0.192	-0.379	3.46	0.2392	0.0000	1.92
Ca	90.71	30.94	0.121	-1.891	36.17	3.8110	0.0000	-0.11
Cl	248.92	80.60	0.172	-0.804	311.69	23.1767	0.0000	-1.01
EC	1009.00	114.63	0.000	-1.830	39964.33	2000.002	0.0000	0.23
Ha	377.02	69.60	0.030	-1.682	1330.14	124.208	0.0000	-0.29
Mg	44.34	3.41	-0.008	-0.990	2.33	0.1801	0.0000	0.38
TDS	720.26	10.40	0.620	0.137	4.30	0.01	0.0000	1.86
Tu	7.43	1.82	0.060	-0.833	3.60	0.2609	0.0000	3.10

Table (۳-۲۵): Effect of power transformation on the first four moments of each series in Al-Hssien station (raw water-water supply)

Pollutant	Before transformation				After transformation			
	Mean	Sd	C <sub>S</sub>	C <sub>k</sub>	Mean	Sd	C <sub>S</sub>	C <sub>k</sub>
Alk	۱۴۱.۳۵۹۲	۱۱.۸۷۵۳	۰.۴۲۸	-۰.۸۹۹	۱.۹۹۳۳	۰.۰۰۴۹۲۴	۰.۰۰۰۰	۰.۰۸
Ca	۱.۴.۰۵۸۳	۳۱.۰۰۳۱	-۰.۱۱۸	-۰.۲۸۵	۵.۰۹۲۶۷	۵.۵۴.۶	۰.۰۰۰۰	۰.۹۹
Cl	۲۷۷.۷۹۱۷	۶۸.۹۸۸۰	-۰.۱۰۳	-۰.۷۵۴	۱۹۴.۵۰۰	۱۴.۷۹۸۹	۰.۰۰۰۰	-۰.۲۴
EC	۱۱۷۴.۰۴۲۵	۹۵۲۱۶۴	-۰.۴۳۷	-۱.۰۳۷	۲۵۷۷.۰۴۰	۱۲۳.۵۵۳۷	۰.۰۰۰۰	۰.۰۳
Ha	۴۶۴.۶۵۱۷	۸۸.۹۱۳۱	-۰.۰۵۲	-۱.۶۹۶	۲۷۷.۰۶۹۲	۱۹.۶۴۰۲	۰.۰۰۰۰	۰.۶۶
Mg	۵۴.۳۳۴۲	۷.۴۸۲۰	-۰.۴۰۴	-۱.۶۲۷	۸۵.۰۶۵۸	۹.۷۳۳۰	۰.۰۰۰۰	-۰.۱۸
TDS	۸۳۷.۸۹۰۰	۱۳.۴۱۷۶	۰.۲۷۸	-۱.۵۳۱	۴۵۰.۲۴۶۷	۱۶.۷۴۰۵	۰.۰۰۰۰	۳.۷۹
Tu	۳۳.۵۰۹۲	۱.۹۳۱۳	-۰.۲۲۳	-۰.۲۳۶	۴۳.۶۷۷۵	۳.۸۸۹۷	۰.۰۰۰۰	۳.۰۵
Q	۱۳۹.۲۱۰۰	۲.۰۱۴۵	۱.۴۸۲	۳.۴۲۶	۵۹۱.۹۱۱۷	۵۴.۳۰۷۵	۰.۰۰۰۰	۲.۵۵

Pollutant	Before transformation				After transformation			
	Mean	Sd	C <sub>S</sub>	C <sub>k</sub>	Mean	Sd	C <sub>S</sub>	C <sub>k</sub>
Alk	۱۳۸.۳۹۰۰	۱۳.۱۱۹۵	۰.۴۹۱	-۰.۸۷۳	۰.۸۶۰۰	۰.۰۰	۰.۰۰۰۰	-۰.۳۶
Ca	۹۹.۳۹۷۵	۲۶.۵۸۴۰	-۰.۱۱۰	-۱.۱۶۸	۵.۰۶۶۳۳	۵.۲۷۳۷	۰.۰۰۰۰	۰.۸۹
Cl	۲۷۰.۴۳۱۷	۶۱.۶۸۲۵	۰.۱۵۵	-۰.۶۸۲	۱۰۴.۳۹۵۰	۶.۷۴۸۸	۰.۰۰۰۰	-۰.۴۸
EC	۱۱۱۶.۵۰۹۲	۱۰۵.۱۴۵۵	-۰.۴۳۰	-۱.۱۰۵	۱۰۵۸۹۶۲	۹۳۱۲۹.۸۸	۰.۰۰۰۰	-۰.۷۵
Ha	۴۵۳.۳۱۰۸	۷۱.۳۸۳۰	-۰.۱۹۱	-۱.۴۷۹	۱۱۰۷.۶۱۳۳	۹۳.۱۸۳۸	۰.۰۰۰۰	۰.۳۱
Mg	۴۶.۳۴۴۲	۲.۶۰۱۴	-۰.۸۵۴	-۰.۴۸۷	۵.۰۶۱۷	۰.۰۹۹۹۸	۰.۰۰۰۰	۳.۲۶
TDS	۸۱۵.۲۴۵۸	۲۹.۵۸۲۵	۰.۴۴۳	-۱.۰۶۵	۷۱۹.۹۱	۳۷.۰۹۴۰	۰.۰۰۰۰	۰.۴۰
Tu	۷.۳۷۱۷	۱.۲۸۷۵	۰.۳۰۲	۰.۲۴۴	۲.۹۳۱۷	۰.۲۶۳۵	۰.۰۰۰۰	-۰.۵۶

Table (3-26): Effect of power transformation on the first four moments of each series in Al-Hashimiya station (raw water-water supply)

Pollutant	Before transformation				After transformation			
	Mean	Sd	C <sub>S</sub>	C <sub>k</sub>	Mean	Sd	C <sub>S</sub>	C <sub>k</sub>
Alk	134.00	17.10	0.223	0.279	1.0370	0.00402	0.0000	1.28
Ca	98.77	34.09	-0.377	-1.324	7.08	0.8020	0.0000	0.04
Cl	278.99	84.44	-0.227	-1.077	41.02	2.8017	0.0000	1.07
EC	1111.77	99.80	0.208	-1.382	3348494.70	349607.7	0.0000	0.07
Ha	444.21	128.71	-0.172	-1.774	408.30	24.029	0.0000	-0.30
Mg	47.79	0.80	0.344	-1.102	60.28	3.1187	0.0000	4.19
TDS	829.33	33.78	-0.189	-1.313	137.78	2.0220	0.0000	-0.12
Tu	31.00	2.04	0.040	0.043	11.71	0.7001	0.0000	0.77
Q	121.30	4.00	-0.371	1.427	428.87	44.3380	0.0000	1.27

Pollutant	Before transformation				After transformation			
	Mean	Sd	C <sub>S</sub>	C <sub>k</sub>	Mean	Sd	C <sub>S</sub>	C <sub>k</sub>
Alk	114.30	23.17	-0.022	-0.883	3.18	0.3700	0.0000	0.27
Ca	88.74	26.01	0.109	-1.413	47.38	4.3107	0.0000	0.10
Cl	274.43	77.23	-0.129	-1.370	434.84	27.7779	0.0000	-0.88
EC	274.41	77.23	-0.129	-1.370	7907.78	442.7284	0.0000	-0.01
Ha	427.21	137.99	-0.277	-1.747	82.028	43.4907	0.0000	-0.70
Mg	40.42	3.07	-0.037	-1.012	37.72	1.7214	0.0000	0.91
TDS	770.10	63.72	0.091	-1.867	310.40	12.7704	0.0000	-0.07
Tu	8.47	2.72	0.480	-1.004	8.71	1.3772	0.0000	-0.38

**Table (4-9): Comparison between monthly means and standard deviations of observed data (7 years) and data generated (7 years) by multisite model for Al-Hindiya station (raw water)**

Pollutant	Series	Mean	Sd.	Raw water											
				Months											
				Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
				Mean Sd.											
Alk	observed	128	10.18	132.67 12.34	132.67 7.01	131.00 1.00	137.33 73.02	131.33 8.08	130.00 0.00	126.37 20.82	121.33 2.31	116.33 0.01	118.00 7.24	119.33 9.29	126.00 4.00
	generated	119.8	27.62	137.97 34.78	127.50 23.20	120.03 21.17	144.82 34.97	126.90 8.73	112.42 19.31	113.06 12.99	140.07 11.04	119.84 37.78	130.72 11.81	131.19 11.24	129.12 12.00
	t-test			0.10	1.84	0.90	0.37	0.92	1.08	0.93	2.90	0.17	2.30	1.41	4.80
	f-test			7.94	9.08	447.70*	24.82	1.17	∞*	2.07	22.84	47.76*	3.08	1.47	9.84
Ca	observed	140	07.69	83.67 27.10	73.67 23.77	70.00 19.29	79.00 19397	89.00 26.21	79.00 0.00	78.67 24.79	71.00 17.09	77.67 19.09	77.00 1.73	70.00 17.30	80.00 23.30
	generated	269.7	48.01	77.79 17.14	77.34 17.09	88.37 2.20	100.99 21.30	91.30 29.93	77.83 20.07	84.14 27.10	87.29 21.02	70.14 27.94	127.70 27.14	107.21 10.00	87.30 11.73
	t-test			0.93	0.38	2.08	2.19	0.10	0.01	0.27	0.99	0.43	3.81	2.79	0.09
	f-test			2.83	2.18	73.00*	1.14	1.30	17.11	1.11	1.79	2.14	247.11*	3.01	4.01
Cl	observed	104.00	07.69	208.67 27.87	199.67 43.43	177.67 21.13	123.67 29.91	124.33 22.19	80.67 0.01	119.00 27.21	103.67 30.10	111.33 29.84	119.67 33.87	128.33 39.72	200.00 78.00
	generated	278.80	47.97	334.43 108.81	293.07 37.87	280.33 37.07	313.71 49.04	281.00 18.97	243.92 70.98	211.20 42.02	233.08 14.01	228.02 32.37	277.41 04.11	274.39 38.84	288.90 27.89
	t-test			7.02	1.94	4.82	4.73	9.30	4.72	3.20	0.90	4.71	4.01	4.00	0.80
	f-test			7.17	1.39	3.08	2.79	1.37	122.48*	2.73	7.28	1.18	2.00	1.00	0.94
EC	observed	1237.00	200.70	1473.00 270.84	1203.00 380.00	1273.33 207.29	1122.00 279.69	1202.77 131.91	1097.77 272.00	1007.77 309.30	1101.77 208.44	1200.00 100.18	1207.00 03.11	1209.00 77.91	1097.00 212.00
	generated	1090.8	87.79	1083.90 82.43	1091.00 77.99	1082.33 38.73	1099.00 77.77	1072.00 82.07	1072.77 129.77	992.20 72.40	1034.00 12.31	1148.27 98.90	1080.44 100.37	1129.77 133.94	1212.44 20.89
	t-test			2.42	0.72	1.08	0.13	2.01	0.20	0.31	0.40	0.70	1.93	0.91	3.13
	f-test			10.40	32.07	28.02	14.82	2.08	4.42	33.10	44.77*	1.03	3.07	3.89	102.99*
Ha	observed	397.00	84.70	430.67 87.93	392.33 77.81	377.67 39.00	340.00 79.79	399.00 84.88	377.00 90.00	400.00 100.78	403.33 103.47	380.67 49.79	400.00 100.07	414.00 170.78	444.00 70.00
	generated	440.90	09.87	392.97 0.71	387.73 28.01	471.80 19.03	440.00 108.07	404.72 80.27	417.71 47.08	477.82 07.00	401.42 12.77	440.37 31.93	442.37 93.74	446.47 31.00	429.80 11.04
	t-test			0.71	28.01	19.03	108.07	80.27	47.08	07.00	12.77	31.93	93.74	31.00	11.04

	t-test			٠.٨٤	٠.١٠	٣.٣٥	١.٣٥	٠.٨٢	٠.٨١	٠.٧٧	٠.٨٠	١.٧٥	١.٧٥	٠.٣٤	١.٩٨
	f-test			٢٣٧.١٤*	٧.٢٦	٤.٠٩	١.٨٣	١.١٢	٤.١٦	٧.٧٤	٦٦.٨*	٢.٤٢	١.٢٦	٢٥.٩٧	٢.٤٩

Table (٤-٩): Continued

Pollutant	Series	Mean	Sd.	Raw water											
				Months											
				Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
				Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Mg	observed	٥٢.٠٠	١٤.٦٥	٥٤.٦٧	٥٠.٣٣	٥٣.٦٧	٤٢.٦٧	٤٦.٣٣	٤٨.٦٧	٥٠.٣٣	٥٣.٠٠	٤٦.٠٠	٥٣.٣٣	٦٠.٠٠	٦١.٦٧
				٤.٥١	٨.١٤	٦.٠٣	١١.٥٩	١٣.٠٥	١٩.٥٠	٢٥.٧٤	١٥.٨٧	١٣.٢٣	٢١.٤٦	٢٩.٤٦	٤.٥١
	generated	٤٧.٠٠	٧.٨٢	٥٠.٢٧	٥٥.٢١	٤٩.٦٥	٤١.١٥	٤٦.٢١	٤٨.٤١	٥١.٦٩	٤٥.٤٥	٤١.٦٩	٤٥.٢٣	٣٧.٨٢	٥٠.٩٥
				٦.٢٥	٢.٥٠	٧.٨٧	٥.٢٦	٤.٠٤	١٤.٦٤	٦.٩٩	٦.٢٥	٧.٨٥	٦.٢٥	٧.٨٨	٦.٠٨
t-test				٠.٩٩	٠.٩٩	٠.٧٠	٠.٢١	٠.٠٢	٠.٠٢	٠.٠٩	٠.٧٧	٠.٤٩	٠.٦٣	١.٢٦	٢.٤٥
f-test				١.٩٢	١٠.٦٠	١.٧٠	٤.٨٦	١٠.٤٣	١.٧٧	١٣.٥٦	٦.٤٥	٢.٨٤	١١.٧٩	١٣.٩٨	١.٨٢
TDS	observed	٧٤١.٠٠	١٢٤.٤٨	٩٣١.٠٠	٨٩٩.٠٠	٧٨٤.٠٠	٧٥٥.٦٧	٧١٥.٠٠	٧٣٥.٠٠	٧٢١.٦٧	٦٨٢.٦٧	٦١١.٠٠	٥٢٧.٣٣	٧٤١.٠٠	٧٩٠.٠٠
				٩٧.٠٠	١١٠.٦٧	١٣٢.٤١	١٣١.١٦	٨٧.٨٨	٢٨.٠٠	٤٤.٤٧	٢٥.٥٧	٣٥.٥٩	٥٢.٥٠	٢٠.٠٠	١٣.٠٠
	generated	٧٤٤.٧٠	٦٤.٢٨	٧٨٩.٩٩	٧٩٠.٥٤	٧٥٣.٥١	٧٤٥.٨١	٧١٠.٢٦	٧٠٦.٨٠	٦٨٦.٢١	٦٩٥.٤٦	٧٣٥.٧٥	٦٩٩.٥٧	٨٣٧.٢٣	٧٨٤.٨٨
				٦٤.٠٦	٢٨.٥٣	٨٦.٠٥	٣١.٨٤	٣٣.٥٠	١٣.١٦	٣٢.٣١	٦٦.٥١	٤٢.٣٨	٨٥.٤٦	٦٩.١٩	٢٨.٦٩
t-test				٢.١٠	١.٦٤	٠.٣٣	٠.١٣	٠.٠٩	١.٥٨	١.١٢	٠.٣١	٣.٩٠	٢.٩٧	٢.٣١	٠.٢٨
f-test				٢.٢٩	١٥.٠٥	٢.٣٧	١٦.٩٧	٦.٨٨	٤.٥٣	١.٨٩	٥.٨٢	١.٤٢	٢.٦٥	١١.٩٧	٤.٨٧
Tu	observed	١٦.٠٠	٨.٦٦	٥.٣٣	٩.٠٠	١١.٠٠	١٦.٠٠	١٥.٦٧	٢٨.٠٠	١٤.٣٣	٢٢.٦٧	٢١.٦٧	١٦.٦٧	١١.٦٧	١٩.٠٠
				٣.٥١	١١.٢٧	٧.٥٥	٦.٥٦	٩.٨١	٣.٠٠	٥.٠٨	١٠.٠٧	٦.٥١	٣.٢١	٢.٨٩	١١.٠٠
	generated	٢٤.٠٠	٦.٧١	١٧.٢٩	١٩.٦١	٢٠.٤٤	٢٥.١٥	٢١.٠٧	٢٦.٢٤	٢٦.٨٦	٢٤.١٠	٢٦.٩٧	٣٣.٦٤	٢٢.٠٩	٢٤.٠٩
				٣.٣٤	١٤.٩٧	١.٠٤	٤.٩٨	٣.٢٩	٩.٧٨	٢.٤٢	٢.٤٢	٤.٥٨	٧.٤٣	٢.٣٠	٤.٢٨
t-test				٤.٢٨	٠.٩٨	٢.١٥	١.٩٢	٠.٩٠	٠.٣٠	٣.٨٩	٠.٢٤	١.١٥	٣.٦٣	٤.٨٩	٠.٧٥
f-test				١.١٠	١.٧٦	٥٢.٧*	١.٧٤	٨.٨٩	١٠.٦٣	٤.٣٢	١٧.٣٢	٢.٠٤	٥.٣٦	١.٥٨	٦.٦١
Q	observed	١٥٥.٠٠	٥١.٧٢	٩٥.١٨	١٣٣.٢٥	١٤٧.٦٤	١٧٨.٠٥	١٦٤.٣٠	١٣٧.١٨	٢٢٧.٤٧	١٥٩.٤٧	٢٠.٢٣٧	١٨٨.٩٩	١٣٣.٣٣	٩٥.٥٧
	generated	٢٠٢.٧٠	١٥.٦٨	٢٠٠.٨٥	١٧٨.٠٧	١٩٦.٩١	١٩٤.٢٨	١٩٧.٠٩	٢٠٦.٤٦	٢٠٧.٣٩	٢١٩.٨٥	٢٢١.٤٧	٢١٠.٥١	٢٠٥.٢٩	١٩٤.٣٦

				٧.٦٦	٨.١٥	١٥.٨٨	١٧.٤٠	١٢.٨٩	١٢.٣٤	٢٠.٠٧	٤.٠٩	٤.٠٦	٧.٣٢	٨.٢٣	١٩.٥٢
	t-test			٥.٦٨	٢.٥٢	٢.١٦	١.١٦	٢.٥٠	١.٨٠	٠.٧٩	١.٩٧	٠.٦٥	٠.٦٨	٣.٢٩	٤.٦٧
	f-test			١٦.٧٠	١٣.٢٩	٥.١٩	١.٠٨	٢.١٠	٢٨.٢٩	٣.٨١	١٦٧.٧٣*	١٥٥.٢٠*	٥٤.٧٦*	١٥.٨٣	٢.٥٢

(t\*) > (t-tab.=١٢.٧١)

(f\*) > (f-tab.=٣٩.٠٠)

Table (٤-١٠): Comparison between monthly means and standard deviations of observed data and data generated by multisite model for Al-Hindiya station (water supply)

Pollutant	Series	Mean	Sd.	Water supply											
				Months											
				Jan. Mean Sd.	Feb. Mean Sd.	Mar. Mean Sd.	Apr. Mean Sd.	May Mean Sd.	Jun. Mean Sd.	Jul. Mean Sd.	Aug. Mean Sd.	Sept. Mean Sd.	Oct. Mean Sd.	Nov. Mean Sd.	Dec. Mean Sd.
Alk	observed	١٢٢.٠٠	١٠.٢٢	١٣.٦٧	١٢٩.٦٧	١٣١.٣٣	١٣١.٠٠	١٢٧.٣٣	١٢٠.٠٠	١١٦.٦٧	١١٢.٠٠	١١٢.٣٣	١١٤.٠٠	١١٦.٠٠	١٢٥.٠٠
	generated	١١٥.٩٠	٢٦.٧٤	١٠.٠٧	٤.٥١	٢.٣١	٨.١٩	١٤.٤٧	٨.٠٠	١١.٥٥	٣.٤٦	٤.٠٤	٥.٢٩	١٢.١٧	٥.٠٠
	t-test			١.٠١.٤١	٩٩.٦٠	١١٤.٨٥	١٢٥.٣٩	١١٦.٢٤	١١٧.٢٨	١٠.٤.٤٦	١٢٤.٢٧	١٥٦.١١	١١٤.٩٤	١٢٢.٠٣	٩٤.٢٤
	f-test			١٥.١٤	٣.٠٠٢	٢٢.٩٧	١٧.٤٩	٢٩.٢٩	٣٤.٢٥	١٢.٧٥	١٤.٩٠	٢٤.٠٨	٤٩.١٢	٢١.٩٧	١٧.٨٦
Ca	observed	٧٥.٠٠	١٨.٦٣	٨٧.٦٧	٧٣.٠٠	٦١.٣٣	٦٨.٠٠	٨٥.٠٠	٧٥.٠٠	٧٤.٠٠	٦٨.٦٧	٧٠.٦٧	٧٣.٦٧	٧٦.٦٧	٨٣.٦٧
	generated	٨٢.٩٠	٢٣.٤٨	٣٣.٢٣	٢٥.٩٨	١٦.٢٩	١٣.٧٥	٢٤.٠٠	١٣.٠٠	٢١.١٧	١٦.٠٤	١٩.٥٥	٦.٤٣	٣١.٦٦	١.٥٣
	t-test			٨٩.٢٤	٩١.٤٠	٧٤.٢٠	٦٨.٢٠	٨٢.٦٨	٧.٠.٤١	٩٤.٦٢	٧٧.٠١	٧٥.٢٩	٩١.٩٠	١٠.٣.٤٠	٧٦.٢٨
	f-test			٢٤.٩٠	٢٨.٩٩	٢٤.٨٦	١٦.٤٧	١٤.٩١	١٢.٠٢	٢٠.٨١	١٩.٤٢	١٠.٣٢	٩١.٥٠	١٥.٨٤	٣٢.٧٩
Cl	observed	١٣٩.٠٠	٥٥.٠٩	١٨٩.٣٣	١٩٤.٠٠	١٥٩.٣٣	١٢١.٦٧	١١٧.٠٠	٧٧.٦٧	١١٢.٦٧	١٠٠.٠٠	١١٥.٣٣	١١٨.٠٠	١١٩.٦٧	٢٤٢.٦٧
	generated	٢٦٥.٧٠	٣٤.٢١	٤٩.٠٥	٤١.٣٩	٢٠.٥٠	٢٣.٢٥	١٠.٨٢	١.٥٣	٢٤.١١	٣١.١٩	٣٥.٥٣	٤.٠٧٣	٤٧.٤٤	٦٢.٥٠
	t-test			٢٦.٠٩٧	٢٨٩.٤٦	٣١٤.٩٨	٢٦٣.١٩	٢٤٤.٤١	٢٧٣.٣٤	٢٦.٠٧٧	٢٢٤.٩٨	٢٤٣.١٦	٢٨٥.٥٢	٢٥.٠٩٦	٢٧٦.٢١
	f-test			٣٧.٨٨	١٣.١٢	٢٣.٣٢	٢٤.٨١	٣.٥٦	١١.٨٣	٤.٠٤٨	٣٣.٤١	٥٦.٥٨	٢٢.٣٨	٣٣.٣٣	١٨.٢١
EC	observed	١٢١٤.٠٠	٢٦٦.٤٣	١٤٤٨.٣	١٢٢٧.٠	١٢٣٢.٦	١٠.٩٩.٦	١٢.١٦.٦	١٠.٧٣.٠	١.٠٦.٠٠	١.٠٧٦.٣	١٢.٤.٦	١١٩٤.٠	١١٨٣.٣	١٥٧٦.٦
	generated	١٠١٦.٥٠	١٠٠.٥٤	٣٨٩.٦٠	٤٢٤.٦٣	٢١٤.١٨	٢٩١.٣٣	١٨٧.٩٥	٣٢٣.٠٠	٣٥٦.٠٧	٢٤٣.٣٧	٣٩.٨٨	٤٢.٥٣	٥٥.٧٧	٢٣٧.٥٠
	t-test			١٠٠.٨.٧	١٠٠٠.٥	١٠.٢٢.٩	١٠.٢٩.٣	٩٦.٠.١٠	٩٥.٠.٧٩	٨٥٩.٢.٠	٩٩١.٧٥	١٠.٢٩.٤	١٠.٣.٠.٦	١١٣٧.٥	١١٧٧.٤
	f-test			٧٣.٧.٠	٥٧.٥٢	١٢٥.٠.٩	١٠.٩.٦.٢	٢٦.٧.٣	٧٣.٣.٣	٨٣.٥.٣	٧٨.٠.٤	٦٢.٩.١	٦٤.٢.٢	٣٢.٨.٢	٢٧.٦.٤

	t-test			1.92	0.92	1.47	0.39	2.20	0.74	0.90	0.07	4.10	3.77	1.23	2.87
	f-test			27.94	04.0*	2.93	7.07	49.44*	19.40*	18.17	9.73	2.49	2.28	2.89	73.83*
Ha	observed	380.00	90.80	448.00	290.00	376.00	306.00	398.77	374.77	391.77	383.00	370.33	388.77	401.77	439.00
				100.18	207.47	40.01	71.88	70.12	77.00	104.80	99.07	21.00	88.72	107.31	27.00
	generated	433.4	04.37	438.07	371.74	409.07	491.77	430.00	434.98	343.90	390.49	391.99	479.93	407.98	474.47
				39.03	100.07	70.40	27.00	09.14	17.73	32.81	47.77	14.07	89.23	77.73	20.48
	t-test				0.17	0.74	1.78	3.47	0.79	1.07	0.48	0.12	1.11	1.27	0.07
f-test				7.42	130.04*	3.47	0.07	1.41	21.17	21.42	4.32	2.18	1.01	2.33	1.04

Table (4-10): Continued

Pollutant	Series	Mean	Sd.	Water supply											
				Months											
				Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
				Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Mg	observed	0.00	12.43	00.00	01.33	03.33	40.77	40.00	43.77	00.33	02.33	47.77	49.77	01.33	00.77
				4.08	8.08	7.11	7.30	7.00	10.00	27.43	20.03	17.87	17.72	18.77	0.01
	generated	01.00	9.47	62.70	00.77	09.37	39.90	07.37	44.93	47.47	03.40	00.91	49.12	00.09	47.49
				1.70	12.40	8.31	4.711	9.18	11.99	9.90	4.47	13.87	8.72	7.21	0.19
	t-test				2.74	0.07	1.01	1.27	2.29	0.14	0.17	0.09	0.27	0.00	0.33
f-test				7.87	2.37	1.80	1.87	1.28	1.30	7.70	20.17	1.48	4.08	9.14	1.13
TDS	observed	72.00	143.30	974.00	879.33	738.77	744.33	741.00	778.00	797.77	771.33	740.00	470.33	787.77	712.00
				124.00	180.10	177.27	139.09	37.30	24.00	40.04	31.90	21.00	07.00	24.00	21.00
	generated	703.90	78.37	701.09	731.90	794.71	720.37	719.70	700.11	719.33	727.03	783.73	731.09	808.00	747.99
				49.30	09.94	81.93	73.09	37.91	72.81	44.09	27.38	09.71	00.19	28.99	72.79
	t-test				3.04	1.34	0.39	0.22	0.70	0.09	2.11	1.83	1.07	7.03	0.49
f-test				7.33	9.03	4.78	4.87	1.09	7.80	1.04	1.47	8.08	1.31	1.40	8.91
Tu	observed	7.00	1.90	4.33	4.00	0.33	0.77	0.77	4.77	0.77	7.00	8.00	7.33	7.77	7.33
				1.10	1.00	1.10	2.02	0.08	2.08	3.07	1.73	3.00	1.03	1.03	2.08
	generated	0.70	0.93	0.00	0.03	0.80	0.28	0.07	0.08	0.37	7.39	0.84	7.43	7.28	0.10
				0.99	1.02	1.40	1.48	1.21	1.07	0.47	1.11	0.72	0.37	0.01	0.20

	t-test			1.34	1.86	0.49	0.23	0.14	0.09	0.17	0.01	1.21	0.11	1.49	1.02
	f-test			1.30	1.04	1.09	2.90	4.30	3.34	42.39*	2.43	17.36	18.06	9.00	108.16*

(t\*) > (t-tab.=12.71)

(f\*) > (f-tab.=39.00)

Table (4-11): Comparison between monthly means and standard deviations of observed data (7 years) and data generated (7 years) by multisite model for Al-Hilla station (raw water)

Pollutant	Series	Mean	Sd.	Raw water											
				Months											
				Jan. Mean Sd.	Feb. Mean Sd.	Mar. Mean Sd.	Apr. Mean Sd.	May Mean Sd.	Jun. Mean Sd.	Jul. Mean Sd.	Aug. Mean Sd.	Sept. Mean Sd.	Oct. Mean Sd.	Nov. Mean Sd.	Dec. Mean Sd.
Alk	observed	127	1.80	126.33 11.06	134.67 8.08	130.33 12.66	134.00 0.00	127.67 9.29	132.00 8.00	126.00 8.19	122.33 9.02	110.67 1.00	118.00 0.29	120.33 8.96	128.00 21.07
	generated	131.1	14.18	124.40 16.09	141.14 19.02	140.34 12.01	139.00 16.26	138.77 16.42	126.72 10.10	120.81 2.80	133.40 12.00	129.91 0.71	133.88 7.23	129.30 10.26	110.63 8.90
	t-test			0.17	0.03	0.99	0.01	1.02	0.63	1.04	1.28	2.14	3.07	1.10	1.16
	f-test			2.12	0.84	1.11	1.08	3.12	3.09	8.26	1.78	3.08	1.87	1.32	0.70
Ca	observed	103	40.66	70.33 9.24	74.00 7.24	72.33 10.00	81.00 21.93	77.67 9.81	76.33 13.01	76.00 12.12	71.33 13.20	70.00 8.19	76.33 10.26	82.00 10.62	70.33 13.01
	generated	203.00	03.60	08.89 8.47	91.97 10.43	79.74 30.29	93.94 26.36	100.24 12.80	73.40 10.67	82.64 14.73	82.13 20.01	92.07 26.13	104.00 11.33	117.10 22.01	74.90 21.08
	t-test			1.08	3.99	0.40	0.60	2.42	0.02	1.42	0.66	1.42	3.20	2.20	0.03
	f-test			1.19	2.79	8.32	1.44	1.70	1.40	1.40	1.48	3.09	10.18	1.22	1.99
Cl	observed	103.00	40.66	184.67 21.13	194.00 38.97	170.33 38.14	147.00 03.71	100.00 40.10	106.00 13.87	110.33 17.04	130.33 41.04	120.33 30.20	167.00 46.36	129.00 03.36	209.33 30.80
	generated	203.80	42.20	280.86 20.88	283.87 21.78	240.00 37.77	202.26 46.83	208.38 43.01	206.97 47.06	222.30 72.48	227.21 23.37	234.67 46.71	291.07 14.88	274.34 47.18	209.06 32.48
	t-test			0.90	3.49	2.10	2.08	3.02	3.60	2.60	4.84	3.39	4.41	2.78	1.80
	f-test			1.02	3.20	1.02	1.31	1.17	11.28	18.09	3.08	1.70	9.71	1.28	1.21
EC	observed	1190	239.73	1272.6 7	1247.6 7	1163.3 3	1163.6 7	1103.6 7	1038.0 0	1010.3 3	1066.6 7	1176.0 0	1209.6 7	1368.6 7	1471.3 3
	generated	1068.20	83.28	270.30 8	420.13 10.63	329.88 11.72	371.03 111.02	220.91 11.60	204.16 8	211.67 98.08	109.89 933.30	74.00 10.82	33.86 10.71	89.67 10.89	144.98 10.89
				02.01	07.90	112.46	43.12	120.30	71.68	42.86	70.20	09.83	84.01	92.33	20.98

	t-test			1.90	0.84	0.28	0.20	0.32	0.38	0.72	0.08	1.91	2.30	3.49	4.42
	f-test			28.03	02.60*	8.70	7.30*	3.03	17.98	24.39	4.01	1.03	7.17	1.07	31.14
Ha	observed	384.00	74.81	307.00	341.77	382.33	361.77	413.77	374.00	377.00	392.33	388.77	394.33	403.33	420.00
	generated	427.80	74.07	40.73	20.00	78.40	76.00	102.04	107.23	119.74	122.30	97.02	71.26	74.01	79.77
				408.97	387.77	413.48	373.74	422.73	349.12	410.70	478.40	471.94	472.90	026.74	377.37
	t-test			3.01	48.27	70.48	74.88	8.00	42.38	74.74	34.27	29.72	34.37	8.82	19.01
	f-test			3.43	1.49	0.00	0.04	0.10	0.38	0.41	1.17	1.43	1.79	2.87	1.17
				1.77	0.02	1.08	1.39	140.03*	7.28	2.07	12.70	10.44	3.18	70.41*	13.47

Table (4-11): Continued

Pollutant	Series	Mean	Sd.	Raw water											
				Months											
				Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
				Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Mg	observed	0.00	13.01	40.77	44.33	48.33	39.33	02.77	0.00	01.00	00.00	02.77	49.77	04.77	07.77
				3.01	0.79	13.32	7.74	21.23	19.08	23.39	21.39	19.87	9.71	9.07	9.29
	generated	43.30	8.70	01.47	37.32	47.11	43.03	39.33	4.03	01.01	42.84	37.78	42.98	47.03	42.01
				7.80	10.83	14.31	13.71	4.97	0.77	2.40	4.44	3.00	7.83	1.87	10.77
t-test				1.31	0.99	0.20	0.41	1.14	0.82	0.00	0.97	1.37	0.93	1.72	1.44
f-test				3.70	3.72	1.10	3.22	18.08	11.37	94.98*	23.19	43.82*	1.04	23.78	2.80
TDS	observed	779.00	182.37	707.74	802.00	777.00	789.33	833.00	709.33	702.77	800.00	771.00	880.77	801.77	731.00
				177.80	307.91	273.01	201.83	301.77	197.34	148.19	70.00	123.00	81.03	170.22	10.00
	generated	710.70	43.01	740.12	779.39	749.47	788.83	717.71	707.04	792.71	710.27	709.07	712.81	774.70	707.02
				13.08	07.30	81.77	47.00	49.23	14.19	30.07	23.80	33.94	20.47	9.97	21.73
t-test				0.13	0.87	0.17	0.00	0.07	0.03	0.11	1.98	0.70	3.01	0.78	1.04
f-test				10.97*	39.02*	11.18	19.20	01.02*	191.40*	24.30	8.71	13.13	10.20	291.49*	2.10
Tu	observed	17.00	0.70	12.33	11.33	13.00	13.77	17.33	19.77	21.33	23.00	27.00	22.33	17.33	13.33
				0.87	0.01	7.24	3.21	1.03	4.73	2.02	1.00	1.73	2.31	2.89	2.89
	generated	27.70	7.48	19.29	27.47	21.78	23.99	24.09	24.88	33.24	31.77	32.47	29.32	37.91	20.01
				1.28	4.44	0.12	7.32	9.08	7.20	3.02	4.70	3.72	0.10	14.39	7.14
t-test				2.02	3.90	1.87	2.02	1.00	1.10	4.77	3.09	2.73	2.17	2.43	3.11

	f-test			٢٤.٦٦	١.٥٤	١.٤٩	٣.٨٨	٣٥.٢٢	١.٧٥	١.٩٥	٢٢.٥٦	٤.٦٢	٤.٨٧	٢٤.٧٩	٤.٥١
Q	observed	١٢٧.٠٠	١٨.٧٥	١١١.٦٧	١٢٨.٢٩	١١٨.١١	١٣٢.٣٠	١١١.٨٤	١٣٨.٤٩	١٣٣.٦٢	١٥٥.١٩	١٣٩.٦٩	١٢٠.٥٨	١٢٧.٠٠	١٠٨.٧٧
				١.٠١١	٣.٦١	٢٢.٥١	٩.٧١	٨.٢٠	١٥.٥٣	١٦.٥٠	١٨.٧٥	٢٥.١٨	١١.٣٧	٢٤.٨٢	٣.٠٣
	generated	١٦٤.٥٠	١٧.٥١	١٣٨.٨٢	١٦٤.٩٥	١٥٧.٠٥	١٦٧.٥٧	١٥٥.٥١	١٩٢.٨٢	١٧٣.٤٤	١٧٣.٦٧	١٦٨.٨٨	١٥٨.٦٨	١٦٨.٤٦	١٥٤.٣٣
				٤.٦٢	٨.١١	١٧.٠٩	١١.٦٤	١١.٨٢	١٠.٣٣	٣١.٧٧	٧.٨٩	٩.٦١	٧.٦٤	١١.٦٦	١٨.١٩
	t-test				٤.٢٣	٧.١٥	٢.٣٩	٤.٠٣	٥.٢٦	٥.٠٥	١.٩٣	١.٥٧	١.٨٨	٤.٨٢	٢.٦٢
f-test				٤.٧٩	٥.٠٥	١.٧٣	١.٤٤	٢.٠٨	٢.٢٦	٣.٧١	٥.٦٥	٦.٨٧	٢.٢١	٤.٥٣	٣٦.٠٤

(t\*) > (t-tab.=١٢.٧١)

(f\*) > (f-tab.=٣٩.٠٠)

Table (٤-١٢): Comparison between monthly means and standard deviations of observed data and data generated by multisite model for Al-Hilla station (water supply)

Pollutant	Series	Mean	Sd.	Water supply											
				Months											
				Jan. Mean Sd.	Feb. Mean Sd.	Mar. Mean Sd.	Apr. Mean Sd.	May Mean Sd.	Jun. Mean Sd.	Jul. Mean Sd.	Aug. Mean Sd.	Sept. Mean Sd.	Oct. Mean Sd.	Nov. Mean Sd.	Dec. Mean Sd.
Alk	observed	١٢٢.٠٠	١.٣٩	١٢٤.٣٣	١٣١.٠٠	١٢٨.٦٧	١٢٨.٣٣	١٢٥.٠٠	١٢٥.٦٧	١٢١.٣٣	١١٣.٦٧	١١٢.٦٧	١١١.٦٧	١١٣.٦٧	١٢٣.٣٣
				١٦.٧٤	٥.٥٧	١٤.٢٩	١.٠٢٦	٧.٢١	٥.١٣	٩.٨٧	٨.٣٣	١٢.٩٠	٥.١٣	٥.٥١	٣.٢١
	generated	١٢٤.٨٠	١٦.٥٥	١٢٨.٠٥	١١٦.٧٨	١٣٠.٣٨	١٣٦.٢٦	١١٦.٨٩	١٣١.٣٩	١٣٠.٨٢	١٠٧.٩١	١٢١.٧٧	١١٦.٥٥	١٢٤.٠٥	١٣٦.٣٠
				١٦.٤٨	١٨.٢٦	٢.٠٦٥	٢.٠٩١	١٢.٦٥	١٥.٢٠	٢٢.٤١	١٤.٤٠	١.٠٥٧	٥.٦٣	٢٧.٣٦	٤.٧٧
t-test				٠.٢٧	١.٢٩	٠.١٢	٠.٥٩	٠.٩٦	٠.٦٢	٠.٦٧	٠.٦٠	٠.٩٥	١.١١	٠.٦٧	٣.٩١
f-test				١.٠٣	١.٠٧٥	٢.٠٩	٤.١٥	٣.٠٨	٨.٧٨	٥.١٦	٢.٩٩	١.٤٩	١.٢٠	٢٤.٦٦	٢.٢١
Ca	observed	٧١.٠٠	١.٠٨٨	٦٩.٦٧	٦٤.٦٧	٧٠.٠٠	٧٧.٦٧	٧٥.٦٧	٦٤.٦٧	٦٥.٦٧	٧٠.٣٣	٦٥.٣٣	٧٤.٣٣	٨٢.٦٧	٧٠.٠٠
				٨.٠٨	٨.٠٥	٩.٥٤	١٨.٧٧	٦.٣٥	١١.٥٠	٩.٤٥	١٣.٢٠	٧.٧٧	١.٠٦٠	١٣.٢٠	١٣.٠٨
	generated	٨٢.٨٠	٢.٠٥٦	٩٨.٦٧	٨٠.٠٢	٧٢.٤٨	٦٠.٠١	٨٢.٢٣	٦٧.٦٦	٨٩.٧٨	٨٧.٩٨	٧١.١٦	٩٤.٥٤	١٠٩.٧٩	٧٩.٥٩
				١٣.٥٠	١٨.٥٦	٣١.٧٠	٨.٢١	٣.٠١	٢٢.٣٤	٣.٠٥	٦.٠٠	٢٧.٠٤	٢٧.٦٩	١٢.١٩	١٧.١٤
t-test				٣.١٩	١.٣٠	٠.١٣	١.٤٩	١.٦٢	٠.٢١	٤.٢١	٢.١١	٠.٣٦	١.١٨	٢.٦١	٠.٧٧
f-test				٢.٧٩	٤.٧٧	١١.٠٤	٥.٢٣	٤.٤٥	٣.٧٧	٩.٦٠	٤.٨٤	١٢.١١	٦.٨٢	١.١٧	١.٧٢
Cl	observed	١٤٨.٠٠	٤٥.١٤	١٧٩.٦٧	١٩٤.٣٣	١٧٢.٠٠	١٤٠.٣٣	١٥٣.٣٣	١٠٣.٣٣	١٠٦.٣٣	١٢٩.٠٠	١١٤.٦٧	١٦٥.٦٧	١٢٢.٣٣	١٩٨.٠٠
				٢٢.٧٤	٤٣.٢٩	٣٨.٩٤	٤٩.٩٦	٣٩.٢١	١٤.١٥	١٤.٥٠	٣٧.٩٩	٤١.٧٩	٤٩.٩٠	٤٥.٣٢	٢٨.٩٣
	generated	٢٥٠.٢٠	٤٣.٥٠	٢٤٦.٥٣	٢٥٠.٧٦	٢٧٤.٤٠	٢٤١.٢٤	٢٧٦.٧٦	١٨٨.١٧	٢٢٠.٠٦	٢٤٠.٣٧	٢٣٤.٣٣	٢٨٥.٦٦	٢٤٠.٦٣	٣٠٤.٠٨
				٤١.٠٦	٦١.٧٢	٢٦.٩٤	٤٣.٨٤	٣٣.٠٢	٥.٦٥	٥٩.٦٣	٣٨.٢٣	٣٤.٤٥	٢.٣٩	١٨.٠٢	٢٦.٧٢
t-test				٢.٤٢	١.٣٠	٣.٧٥	٢.٦٣	٤.١٧	٩.٦٤	٣.٢١	٣.٥٨	٣.٨٣	٣.٨٦	٤.٢٠	٤.٦٧
f-test				٣.٤٢	٢.٠٣	٢.٠٩	١.٣٠	١.٤١	٦.٢٧	١٦.٩١	١.٠١	١.٤٧	٥.٩٩	٦.٣٣	١.١٧
EC	observed	١١٧٤.٠٠	٢٣١.٤٢	١٢٤٧.٠	١١٩٨.٦	١١٤٧.٠	١١٣٤.٠	١١٤٧.٠	١٠٣٢.٦	١٠٢٢.٦	١٠٣٨.٠	١١٤٢.٦	١١٩٦.٦	١٣٤١.٠	١٤٣٩.٠

	generated	100.00	80.03	273.20	389.33	302.80	338.47	220.36	241.84	217.20	193.17	73.00	38.40	91.00	133.71
				1099.42	921.03	974.98	1079.22	993.72	904.00	929.80	997.07	997.82	1031.08	1047.47	1047.02
	t-test			70.03	99.79	114.43	97.70	30.01	84.78	104.90	38.47	40.07	00.09	110.14	47.10
	f-test			0.94	1.20	0.80	0.32	1.19	0.03	1.77	0.37	3.24	4.04	3.07	4.79
Ha	observed	377.00	72.02	300.33	343.00	378.77	344.77	414.33	379.00	371.33	380.33	378.33	373.77	410.33	407.77
				34.39	31.00	72.77	73.02	112.48	100.07	100.10	109.13	84.07	70.08	70.34	77.02
	generated	387.00	01.38	439.29	314.93	387.03	424.47	411.34	390.73	388.99	379.72	307.01	397.47	393.08	360.97
	t-test			43.33	33.70	47.47	8.72	44.17	23.92	74.10	00.23	73.10	10.39	78.72	39.29
	f-test			2.79	1.07	0.17	2.17	0.04	0.30	0.37	0.01	0.33	0.04	0.27	0.92
					1.09	1.18	2.40	04.30*	7.48	19.29	2.01	4.72	1.32	02.22*	1.09

Table (4-12): Continued

Pollutant	Series	Mean	Sd.	Water supply											
				Months											
				Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
				Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Mg	observed	49.00	13.34	44.77	43.33	47.00	37.77	03.77	48.33	47.77	02.00	03.77	48.00	00.33	07.77
				20.8	4.73	13.40	0.87	23.77	18.10	21.08	20.22	19.89	8.19	8.97	10.12
	generated	43.9	7.97	41.07	39.01	03.78	40.14	40.91	43.78	40.70	40.71	40.72	47.33	47.12	33.30
	t-test			3.47	7.17	7.79	1.91	4.40	8.10	7.77	7.23	8.97	0.87	4.90	2.07
	f-test			1.33	0.80	0.70	0.98	0.07	0.40	0.17	0.01	0.74	0.29	0.70	3.88
TDS	observed	773.00	187.91	000.77	807.00	781.00	737.33	878.77	727.00	707.00	808.00	777.00	884.00	847.00	718.00
				03.00	377.43	207.47	140.02	338.37	178.37	171.10	90.00	137.00	97.27	131.88	29.00
	generated	724.90	01.87	707.71	721.00	737.88	780.39	730.77	707.40	701.74	740.88	727.00	733.07	719.70	733.07
	t-test			22.73	8.00	10.147	0.10	117.71	23.71	73.72	34.00	31.30	11.13	37.82	30.33
	f-test			0.99	0.74	0.28	0.71	0.74	0.70	0.47	1.21	0.49	2.79	1.70	4.37
Tu	observed	7.00	2.27	0.04	1998.0*	7.44	792.94*	8.28	0.43*	7.40	7.79	19.10	74.82*	13.82	1.48

	generated	V.0.	V.V.	1.10	1.73	0.08	0.08	1.03	2.02	1.10	2.31	2.02	2.02	1.16	2.02
				7.00	1.92	8.11	7.78	0.81	7.78	8.03	9.71	0.99	8.00	10.07	7.37
				2.70	1.82	3.00	2.99	1.90	3.07	1.09	2.02	3.03	2.09	3.09	3.01
				2.27	0.73	1.99	1.77	0.83	0.11	1.91	1.78	0.30	0.17	1.08	0.71
	t-test			0.01	1.11	37.11	27.08	1.01	1.11	1.91	1.31	1.10	1.10	1.81	1.11
	f-test														

$(t^*) > (t\text{-tab.}=12.71)$

$(f^*) > (f\text{-tab.}=39.00)$

Table (1-13): Comparison between monthly means and standard deviations of observed data (3 years) and data generated (3 years) by multisite model for Al-Hssien station (raw water)

Pollutant	Series	Mean	Sd.	Raw water												
				Months												
				Jan. Mean Sd.	Feb. Mean Sd.	Mar. Mean Sd.	Apr. Mean Sd.	May Mean Sd.	Jun. Mean Sd.	Jul. Mean Sd.	Aug. Mean Sd.	Sept. Mean Sd.	Oct. Mean Sd.	Nov. Mean Sd.	Dec. Mean Sd.	
Alk	observed	126	12.70	130.77	132.00	130.00	127.00	122.00	136.00	117.00	131.00	110.00	100.33	130.00	111.00	
	generated	137.1	12.07	9.00	8.01	9.01	7.00	7.00	127.80	131.37	131.37	137.02	131.17	117.19	139.71	
	t-test			22.12	11.83	3.77	1.78	11.00	8.03	17.83	17.09	1.32	10.01	7.82	0.37	
	f-test			0.37	0.71	2.10	1.77	1.99	1.07	1.78	0.71	2.71	1.17	1.11	0.08	
Ca	observed	100	13.70	77.00	71.77	77.33	81.77	92.33	70.00	71.77	71.00	80.77	80.77	87.77	77.77	
	generated	261.7	71.02	3.00	7.77	12.77	8.71	0.01	13.00	7.01	1.00	22.01	17.39	3.01	2.02	
	t-test			89.70	97.19	100.11	80.70	70.81	179.70	78.09	102.93	80.00	89.03	101.19	131.18	97.80
	f-test			70.10	10.37	31.01	13.81	11.77	19.72	23.09	31.18	17.79	2.11	1.71	21.97	21.97
Cl	observed	100.00	13.70	211.00	200.00	190.77	171.77	133.33	82.00	121.00	120.77	171.77	111.77	111.77	181.00	
	generated	261.7	70.98	31.00	18.19	19.09	11.37	21.00	2.00	21.00	21.00	17.31	22.00	32.00	2.00	
	t-test			277.08	211.37	328.11	293.09	179.70	289.90	289.90	277.70	227.39	209.00	207.72	337.08	
	f-test			10.72	11.21	00.91	9.72	81.03	18.82	31.19	22.93	10.88	81.97	20.19	29.31	
				0.87	1.37	3.89	2.28	0.71	19.03*	1.38	7.09*	2.39	2.10	0.28	9.02	
				8.83	7.10	8.08	10.27*	10.91	88.00*	2.07	1.11	18.12	13.20	1.08	210.21*	

EC	observed	1268.00	237.78	1447.7 V	1370.7 V	13.8.3 3	129.7 V	1277.7 V	1.70.7 V	1217.0 .	1.33.7 V	1337.0 .	1179.3 3	1414.7 V	1274.7 V
	generated	1148.40	9.00	377.00	307.12	347.17	27.30	174.00	24.00	3.00	127.00	310.70	178.22	41.00	170.00
	t-test			1117.7 0	1140.1 A	1.98.3 7	1170.2	1.98.2 V	1.79.0 9	11.2.3 1	1170.4 9	1147.2	1244.8 2	1248.0 0	1188.9 V
	f-test			88.72	127.10	98.21	139.70	20.97	07.42	23.18	29.12	117.9	24.07	11.71	97.71
Ha	observed	417.00	73.23	377.77	388.77	413.77	474.33	010.33	374.77	481.00	434.00	398.77	377.77	431.00	307.33
	generated	472.00	1.401	20.00	07.00	9.79	8.70	77.00	77.00	19.00	94.00	79.00	77.27	00.00	9.00
	t-test			383.49	499.91	494.77	447.77	028.48	432.04	478.41	427.10	488.93	0.77	432.09	490.80
	f-test			239.78	107.7	124.08	77.70	14.44	38.07	47.79	74.22	121.97	118.08	00.37	28.7
				0.14	0.84	0.91	0.37	0.14	1.29	0.9	0.11	1.08	1.70	0.2	7.34
				88.30*	7.47	1.89	1.43	3.70	2.97	7.04	1.70	2.38	2.40	1.01	8.72

Table (4-13): Continued

Pollutant	Series	Mean	Sd.	Raw water											
				Months											
				Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
				Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Mg	observed	04.00	14.77	44.77	49.33	03.77	71.77	79.00	40.77	78.33	72.00	47.77	39.77	01.77	48.00
				4.01	9.71	14.29	14.00	14.00	8.00	8.00	21.00	7.43	4.01	10.00	4.00
	generated	02.30	14.84	04.80	49.40	43.44	03.40	00.77	02.37	77.38	00.87	43.01	37.31	07.84	08.71
				38.87	21.87	8.48	11.81	9.23	9.90	1.79	1.00	18.07	12.84	9.9	8.74
t-test				0.40	0.01	1.07	0.78	1.37	0.89	1.38	0.40	0.37	0.30	0.00	1.93
f-test				74.24*	0.17	2.83	1.42	2.30	1.37	1.71	4.00	8.34	8.11	2.84	4.77
TDS	observed	797.00	100.02	700.33	729.33	084.77	702.33	730.00	727.33	717.33	772.00	807.00	840.00	737.33	709.00
				93.73	48.70	118.79	100.1	24.08	27.79	27.08	147.37	83.23	21.93	11.80	28.00
	generated	221.40	10.17	227.71	212.72	237.74	214.73	218.28	218.12	217.02	231.20	222.47	214.33	221.30	224.04
				9.03	17.38	7.92	7.48	12.09	9.70	4.87	7.03	2.90	2.11	4.07	9.42
t-test				8.72	13.90*	0.07	40.04*	32.41*	24.93*	20.79*	7.39	12.14	49.19*	71.34*	28.43*
f-test				97.03*	7.87	294.78*	4.03	3.01	7.07	29.79	0.24*	797.00*	108.02*	8.48	8.84
Tu	observed	23.00	9.10	20.00	20.00	20.00	22.00	24.00	31.77	34.77	20.00	27.77	27.77	12.00	12.00

	generated	32.70	4.73	10.00	0.07	2.00	1.00	2.00	3.01	0.08	0.00	20.21	10.41	3.00	4.00
				34.04	30.76	31.41	28.93	20.01	31.43	30.77	33.43	38.19	34.72	34.73	33.94
	t-test			4.42	1.40	1.87	7.14	7.44	3.33	2.40	2.92	4.24	2.77	2.71	1.77
	f-test			2.22	3.24	7.22	1.77	0.27	0.09	0.76	0.00	0.97	1.30	9.70	8.76
Q	observed	113.00	39.79	77.92	97.30	109.34	171.77	74.29	97.07	92.23	170.93	130.30	132.98	123.41	83.84
				22.89	19.98	20.30	3.18	31.82	41.14	48.26	2.30	29.88	33.03	31.20	30.06
	generated	138.90	17.93	111.01	131.80	142.00	100.93	133.89	144.30	109.93	140.09	138.42	139.32	148.00	120.07
	t-test			24.74	9.14	8.32	17.47	7.38	17.02	24.10	0.13	9.76	8.48	11.07	8.07
	f-test			1.70	2.72	2.16	2.02	3.18	1.88	2.17	7.24	0.17	0.32	1.32	2.26
				1.17	4.78	9.20	30.18	24.87	0.84	4.01	4.77	9.37	10.21	7.96	14.38

(t\*) > (t-tab.=12.713)

(f\*) > (f-tab.=39.00)

Table (4-14): Comparison between monthly means and standard deviations of observed data and data generated by multisite model for Al-Hsien station (water supply)

Pollutant	Series	Mean	Sd.	Water supply											
				Months											
				Jan. Mean Sd.	Feb. Mean Sd.	Mar. Mean Sd.	Apr. Mean Sd.	May Mean Sd.	Jun. Mean Sd.	Jul. Mean Sd.	Aug. Mean Sd.	Sept. Mean Sd.	Oct. Mean Sd.	Nov. Mean Sd.	Dec. Mean Sd.
Alk	observed	123.00	11.72	130.00	130.00	130.00	128.77	127.77	120.00	122.33	117.00	103.33	107.00	131.77	127.77
				10.00	9.04	9.17	7.03	2.02	10.00	2.02	4.00	0.77	14.00	11.00	7.01
	generated	137.30	14.47	140.02	127.10	139.08	147.73	138.04	137.30	131.07	137.30	137.01	127.47	128.70	140.97
	t-test			20.17	4.32	14.89	21.78	20.74	10.93	10.21	10.42	10.20	7.82	14.27	1.22
f-test			0.77	0.74	0.90	1.47	0.99	1.91	0.98	2.32	3.74	2.28	0.28	0.04	
Ca	observed	77.00	12.42	70.00	73.00	77.00	83.33	91.00	78.00	71.00	71.77	78.33	81.00	84.77	70.00
				30.00	7.21	12.29	8.33	0.00	18.00	7.00	10.00	20.74	17.82	0.08	1.00
	generated	89.00	20.01	100.79	77.01	73.40	87.89	77.80	77.09	100.20	80.93	83.70	107.79	107.08	99.48
	t-test			47.87	27.80	37.81	13.09	13.01	13.13	4.10	7.00	23.47	37.81	23.00	2.70
f-test			1.29	0.18	0.11	0.00	2.88	0.03	8.34	1.32	0.30	1.14	1.79	20.74*	
Cl	observed	149.00	39.47	207.00	198.00	188.33	171.00	133.00	93.00	127.00	117.00	100.00	139.00	129.00	144.77
				27.00	10.09	10.89	10.09	27.00	3.00	20.00	20.00	48.38	23.08	37.00	17.00



TDS	observed	921.00	72.17	804.77	870.77	887.00	902.77	918.77	934.77	930.00	920.77	921.00	840.33	1010.00	1049.00
				20.00	11.93	7.00	12.00	20.11	29.14	3.71	24.01	0.23	38.21	9.00	17.00
	generated	808.40	06.01	820.87	797.37	809.30	773.08	883.01	740.24	777.08	782.92	827.39	783.81	807.11	814.29
				70.77	38.17	108.09	38.32	47.41	77.77	7.07	34.07	47.79	22.19	37.02	20.07
t-test				0.78	3.18	0.44	7.00	1.20	4.73	37.97*	0.88	2.36	2.22	7.41	10.24*
f-test				8.76	10.23	20.496*	9.40	0.07	0.23	3.30	2.07	1.17	2.97	17.02	1.47
Tu	observed	11.00	3.06	9.77	9.77	9.33	9.77	10.00	12.77	17.00	10.00	9.77	13.00	8.00	7.77
				3.01	2.02	1.10	0.08	0.00	2.02	2.00	0.00	4.73	3.00	2.00	1.03
	generated	8.00	2.78	7.12	7.82	0.87	7.37	7.78	7.20	9.24	13.44	8.47	10.77	7.79	7.77
				3.23	2.02	2.07	3.04	1.03	1.99	1.78	3.80	2.70	3.24	0.73	0.78
t-test				0.93	0.99	2.14	1.12	0.41	2.92	4.48	0.70	0.38	0.90	1.00	0.00
f-test				1.18	1.07	4.97	37.20	∞*	1.70	1.42	1.79	2.97	1.24	10.08	0.07

(t\*) > (t-tab.=12.71)

(f\*) > (f-tab.=39.00)

Table (4-10): Comparison between monthly means and standard deviations of observed data (3 years) and data generated (3 years) by multisite model for Al-Hashimiya station (raw water)

Pollutant	Series	Mean	Sd.	Raw water											
				Months											
				Jan. Mean Sd.	Feb. Mean Sd.	Mar. Mean Sd.	Apr. Mean Sd.	May Mean Sd.	Jun. Mean Sd.	Jul. Mean Sd.	Aug. Mean Sd.	Sept. Mean Sd.	Oct. Mean Sd.	Nov. Mean Sd.	Dec. Mean Sd.
Alk	observed	123.00	17.17	133.33	131.00	129.77	127.00	121.77	137.33	127.33	121.77	93.77	110.00	110.33	128.77
				20.03	14.11	13.43	12.77	14.01	4.72	2.08	0.79	13.00	7.24	12.87	20.01
	generated	128.00	18.99	130.94	137.13	130.48	130.40	140.03	129.97	128.80	133.73	120.08	118.07	113.77	117.10
				28.39	24.84	19.94	24.11	28.07	0.93	20.47	24.23	11.00	12.31	12.77	9.72
t-test				0.12	0.37	0.07	0.28	1.30	1.70	0.17	0.84	3.12	1.08	0.10	0.74
f-test				1.90	3.10	2.20	3.07	4.17	1.70	149.87*	18.13	1.01	3.89	1.01	7.77
Ca	observed	104.00	03.01	79.00	78.77	78.33	78.00	74.77	77.77	77.77	77.33	77.77	80.00	92.00	70.33
				10.39	9.29	18.34	21.77	27.10	17.72	14.00	3.01	17.00	4.37	27.07	3.07
	generated	277.00	02.32	77.72	90.11	102.27	100.30	103.78	82.19	87.41	77.82	98.89	107.89	107.78	97.40
				7.84	19.28	40.73	27.29	17.77	21.37	18.22	27.92	0.30	0.87	22.83	22.89
t-test				1.21	1.74	0.93	1.37	1.00	0.91	1.47	0.03	3.22	7.71	0.78	2.03
f-test				2.31	4.31	4.93	1.09	2.33	1.47	1.08	63.27*	9.01	1.81	1.30	00.97*

Cl	observed	104.00	03.01	19.77	219.77	191.77	17.77	173.77	94.33	1.0.33	119.00	122.00	13.0.33	124.77	231.33
				42.02	3.0.9	32.30	30.20	41.14	18.77	12.86	34.70	14.00	37.70	01.79	49.04
	generated	270.70	03.06	274.38	28.47	32.03	246.38	242.47	28.37	233.23	227.13	229.48	340.47	227.87	37.91
	t-test			19.33	08.81	32.92	06.70	08.41	11.40	37.92	28.02	11.71	33.23	28.37	.49
EC	f-test			3.10	1.09	4.84	2.22	1.91	14.77	0.70	4.17	14.00	7.42	3.00	4.03
				4.84	3.82	1.04	2.09	2.02	2.71	8.79	1.02	1.43	1.28	3.32	1.221
	observed	1228.00	277.42	1387.7	9.0.77	13.00	1293.7	1201.7	1.293	1.387	1184.0	1191.0	1319.0	1372.3	1407.7
				3.326	313.87	4.8.0.7	312.40	277.17	239.77	321.27	174.17	0.00	70.04	240.37	124.78
Ha	generated	114.70	1.4.14	1140.8	1.437	1177.0	110.0	1.077.0	1.99.4	1.912	1.32.0	1232.8	1218.1	1239.7	1191.1
				17.12	2.04	84.77	179.97	70.8.0	1.0.72	87.17	3.98	40.80	81.40	9.77	07.71
	t-test			1.20	.77	.08	.79	1.11	.47	.27	1.49	1.07	1.07	.94	3.37
	f-test			3.18	233.49	23.18	3.01	17.37	0.47	13.90	31.70	1.19	1.17	73.79	4.84
Ha	observed	401.00	88.37	409.33	30.77	420.77	423.00	434.77	372.77	381.00	420.33	374.77	404.00	413.33	403.00
				08.39	72.74	147.29	171.00	187.30	74.84	81.00	77.20	0.01	01.74	110.24	8.89
	generated	477.80	0.08	487.97	437.37	490.48	438.07	01.0.7	439.87	440.01	427.41	404.37	494.77	010.00	471.44
				38.80	8.18	94.42	40.28	79.01	33.97	19.19	0.70	47.13	23.72	33.40	40.23
TDS	t-test			1.94	2.38	.79	.10	.74	1.09	1.33	.11	2.97	2.77	1.47	2.20
	f-test			2.27	08.74	2.40	14.30	0.00	3.74	18.04	2.32	7.0.9	4.74	11.87	20.89

Table (4-10): Continued

Pollutant	Series	Mean	Sd.	Raw water Months											
				Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
				Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Mg	observed	03.00	14.72	08.33	40.00	04.77	07.00	71.00	49.00	01.33	00.00	01.77	48.00	47.77	00.00
				7.23	11.14	24.77	28.79	29.47	8.77	11.93	13.89	7.01	11.03	18.10	1.73
	generated	47.70	0.90	00.30	47.73	43.00	44.30	48.91	47.77	49.97	48.08	39.91	44.79	49.33	04.17
				2.30	1.47	1.71	3.72	7.70	2.22	1.01	3.29	4.73	7.28	2.97	4.77
TDS	t-test			.78	.18	.78	.70	.79	.27	.20	.84	2.00	.42	.17	.28
	f-test			9.88	1.13	20.97*	73.20*	14.83	10.22	72.42*	17.82	1.98	3.37	37.30	7.70
TDS	observed	987.00	70.89	972.00	970.33	978.33	987.77	994.77	1003.00	997.33	990.00	983.33	83.33	1027.33	1121.77
				8.00	9.07	11.37	12.77	10.14	17.02	7.43	30.32	03.12	47.48	7.01	24.00



	t-test			32.72	19.16	30.67	20.88	17.34	12.00	10.91	22.72	30.38	19.21	17.77	7.12
	f-test			1.73	0.70	0.37	0.21	0.99	1.28	0.78	0.70	0.13	1.09	0.20	2.09
				9.74	3.02	2.32	1.07	2.73	2.90	4.87	17.80	74.20*	1.40	1.42	2.03
Cl	observed	149.00	01.78	190.33	203.77	190.77	107.33	100.33	93.33	100.33	118.77	112.77	121.33	118.77	220.77
	generated	270.00	33.04	280.99	299.44	311.67	277.29	270.71	249.87	240.28	201.07	270.49	272.98	274.20	300.07
	t-test			30.01	12.33	38.40	40.37	47.72	24.63	22.41	40.74	40.37	7.30	19.98	22.01
	f-test			3.18	4.07	4.73	3.77	2.93	9.10	10.00	4.13	7.01	7.32	0.08	2.70
					2.01	7.70	2.09	1.00	1.04	2.07	4.11	2.00	8.94	22.81	7.07
EC	observed	120.700	247.41	1311.00	1178.70	1289.30	1201.30	1177.00	1007.70	1000.30	1101.70	1134.70	1283.30	1341.70	1332.30
	generated	1077.70	88.01	293.01	347.04	429.48	303.71	239.77	228.00	310.89	187.70	77.00	107.47	271.82	121.09
	t-test			1180.40	1073.20	1049.20	1104.70	1023.30	907.98	948.39	983.90	1130.70	1091.00	1126.40	1147.40
	f-test			10.71	29.18	77.17	99.82	20.43	08.80	73.01	70.80	31.88	10.29	77.17	41.20
					0.74	0.07	0.97	0.79	1.03	0.37	0.28	1.47	0.09	3.09	1.32
Ha	observed	397.00	88.00	401.77	347.33	410.33	414.33	419.77	384.00	307.00	400.03	400.00	422.77	427.00	374.77
	generated	408.70	07.04	472.79	404.48	06.87	472.89	487.98	470.09	470.19	432.18	387.07	490.77	437.30	491.80
	t-test			08.27	37.32	97.23	71.31	13.98	20.97	07.79	84.71	20.74	20.91	47.02	42.47
	f-test			2.01	1.34	0.96	0.48	0.74	1.00	2.10	0.01	0.00	2.00	0.12	3.47
					9.27	2.90	2.18	7.11	182.34	17.88	1.28	1.74	1.97	4.70	9.00

Table (4-16): Continued

Pollutant	Series	Mean	Sd.	Water supply											
				Months											
				Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
				Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Sd.	Sd.	Sd.	Sd.	Sd.	Sd.	Sd.	Sd.	Sd.	Sd.	Sd.	Sd.				
Mg	observed	01.00	12.89	08.00	43.33	47.00	02.33	08.33	02.00	49.00	01.77	02.77	02.33	00.77	00.00
				2.70	9.71	13.00	21.39	28.31	13.11	9.74	13.32	11.00	14.07	17.07	7.08
	generated	40.40	0.72	48.79	41.22	00.00	41.81	47.84	48.24	40.09	41.09	39.84	43.22	01.09	47.88
				3.11	7.32	7.09	3.74	3.77	7.01	3.42	1.78	3.18	1.08	0.04	7.00

	t-test			3.90	0.30	0.30	0.84	0.70	0.40	0.08	1.30	2.01	1.08	0.04	0.40	
	f-test			1.38	1.72	2.93	34.03	03.79*	4.76	7.90	72.86*	13.08	80.04*	8.94	1.33	
TDS	observed	778.00	111.36	743.77	717.33	70.733	080.77	792.33	703.77	087.00	794.77	901.00	773.33	701.00	733.33	
				07.72	24.08	01.70	10.21	47.98	21.08	30.01	172.70	73.00	83.74	40.04	30.00	
	generated	770.70	77.78	772.06	832.81	823.74	797.41	803.08	790.07	774.00	799.34	771.02	769.03	811.00	769.41	
				03.86	39.41	77.93	90.91	97.36	48.09	73.41	20.17	03.18	18.70	44.97	27.78	
	t-test				2.71	8.04	4.46	4.01	1.79	3.01	2.07	0.00	2.49	0.09	3.16	0.94
	f-test				1.14	2.07	1.78	79.28*	4.07	0.20	3.19	47.00*	1.88	20.00	1.26	1.74
Tu	observed	13.00	8.49	7.77	7.00	8.77	9.00	10.00	10.33	12.33	14.00	31.77	21.33	12.33	7.77	
				2.89	2.70	3.79	1.73	2.70	4.01	3.79	1.00	11.00	11.02	7.81	2.89	
	generated	9.20	3.76	11.44	14.73	10.30	10.02	9.30	7.14	8.87	7.32	8.93	9.90	8.11	7.08	
				2.41	0.97	2.33	1.10	1.70	0.94	3.90	2.76	4.31	7.97	2.79	0.97	
	t-test				2.20	4.74	0.73	0.80	0.38	3.49	1.09	4.03	3.21	1.02	1.00	0.02
	f-test				1.44	7.46	2.70	2.26	2.29	23.02	1.09	7.72	7.12	2.00	7.41	4.27

(t\*) > (t-tab.=12.71)

(f\*) > (f-tab.=39.00)