Risk Assessment of Water Supply System in Babylon Governorat: A Stochastic Approach

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Abstract

The present study was conducted to evaluate the risk of water supply system in Babylon Governorate from the intake through to the consumer's tap. Water failure may occur at any components of water supply system. Therefore, risk was calculated for exposure to contaminants in raw, treated, and distributed tap water.

The risk assessment process was concerned on chemical and microbial contaminants in water. The hazard index (HI) was calculated for noncarcinogenic chemicals (Hg, Cd, Cu, Zn, NO_3, and Cl(free)) in water , while the risk was calculated for carcinogenic chemicals (Pb, As, and Cr) and microbial contaminant represented E.coli. Both of hazard index and risk were conducted for raw, treated, and distributed tap water and the results were compared with the EPA limitations in order to show the potential health risks of these chemicals to local primary users of water from water supply system.

In this study the statistical models which are described the relations between the water quality parameters and human health were established, the statistical analysis results revealed significant correlation between the number of infections of cholera, diarrhea, typhoid and hepatitis disease with water quality parameters of raw, treated , and distributed tap water.

الخلاصة

أجريت الدراسة الحالية لتقييم الخطر في نظام تجهيز المياه في محافظة بابل من المصدر إلى حنفية المستهلك. وان حدوث الفشل محتمل في أي مكون من مكونات نظام تجهيز المياه لذا تم حساب خطر التعرض للملوثات في المياه الخام والمعالجة والمستهلكة.

أجريت عملية تقييم الخطر للملوثات الكيميائية والميكروبية في المياه، للمواد غير المسرطنة (الزئبق ، الكادميوم ، النحاس، النترات والكلورين الحر) وذلك بحساب مؤشر الخطر . بينما تم حساب الخطر للمواد المسرطنه (الرصاص، الزرنيخ، والكروم) والملوثات المكروبية المتمثلة بالبكتريا البرازية وان كلاً من مؤشر الخطر والخطر حسب للمياه الخام والمعالجة والمستهلكة ومن ثم تمت مقارنة النتائج مع محددات وكالة حماية البيئة لتوضيح الأخطار المحتملة للملوثات على صحة السكان المحليين الذين يستخدمون المياه من نظام تجهيز المياه.

في هذه الدراسة وضعت الموديلات الاحصائيه لتوضيح تأثير المياه الملوثة على صحة الإنسان . كشفت نتائج التحليل الإحصائي بوجود ارتباط معنوي بين عدد الإصابات لمرض الكوليرا، الإسهال، التيفوئيد والتهاب الكبد الفيروسي مع خصائص المياه الخام والمعالجة والمستهلكة .

1. Introduction

Drinking water is essential to life; Water is used by plants and animals to sustain their lives. In addition, man needs water for domestic purposes and for his industrial and agricultural activities. Water can be a source of exposure to pathogens and chemical, physical and radiological contaminants. For waterborne pathogens, including bacteria, viruses, and protozoa, drinking water is a major contributor to human exposures. Public health experts generally agree that microbiological pathogens are the most important risk posed by drinking water. These pathogens can cause disease outbreaks that result in acute health problems for substantial proportions of an exposed population. The provision of safe drinking water to the majority of the world's population is one of the great public health achievements of recent centuries **(Boyd, 2006).**

Water supply system provides the general population with water in sufficient quantity and quality. A typical modern water supply system comprises the water source (groundwater or surface water including the catchment basin), transmission

mains, treatment plants and a distribution network which includes pipes and distribution tanks. **(Sadiq et al., 2007).**

To achieve the aims of this study is to assess risk associated with water supply in Babylon governorate the chemical and microbial risk were calculated for raw water (shatt al-Hilla) in six location as shown in Fig. (1), treated , and distributed tap water. Also this study was conducted to assess the ill effects of water pollution on human health in Al-Hilla city (the center of Babylon governorate).

2. Risk Assessment

Risk assessment is a useful tool for estimating the likelihood and severity of risks to human health, safety and the environment and for informing decisions about how to manage those risks. The term "risk assessment" refers to a document that assembles and synthesizes scientific information to determine whether a potential hazard exists and/or the extent of possible risk to human health, safety or the environment **(Beck, 2006).**

Risk assessment is used for many purposes by Governments . At a broad level, risk assessments can be used for priority setting, managing risk, and informing the public and other audiences. The purpose of the assessment may influence the scope of the analytic work, the type of data collected, the choice of analytic methods, and the approach taken to reporting the findings. Accordingly, the purpose of an assessment should be made clear before the analytical work begins **(Davies, 1996).**

The risk assessment process is typically described as consisting of four basic steps: **(EPA, 2000).**

- **Hazard identification**: the chemicals present at the site or facility and their characteristics (source analysis).
- **Exposure assessment**: determine the size and nature of the population exposed and the route, amount and duration of the exposure (pathway analysis). The mean exposure concentration of contaminants is used with exposed population variables and assessment – determined variables to estimate contaminant intake.

The general equation for ingestion of water-borne chemical is **(Davis, and Masten 2004)**:

$$I = \frac{C \times IR \times EF \times ED}{BW \times AT} \qquad \text{…….. (1)}$$

Where:
I= intake by ingestion (mg / kg.day)
C= chemical concentration in water (mg/L)
IR= ingestion rate (L/day)
EF= exposure frequency (day/year)
ED= exposure duration (years)
BW= body weight (kg)
AT= average time (period over which the exposure is averaged -days).
=ED × 356 days/year .

- **Dose-response assessment (toxicity assessment)**: to characterize the relationship between various doses administered and the incidence of health effect (receptor analysis).
- **Risk characterization**: the determination of number that express risk.Risk characterization is the calculate of risk for both noncarcinogens and carcinogens for all receptors that may be exposed to hazardous waste. Human health risk estimates of noncarcinogens are based on the following calculation :

$$HI = \frac{I}{RfD} \qquad \text{…….. (2)}$$

Where:
HI = hazard index (dimensionless)
I= intake (mg/kg.day)
RfD= reference dose (mg/kg.day)

Human health risks of carcinogens are based on the following calculation:

$$Risk = CDI \times SF \quad \text{……. (3)}$$

Where:
Risk = the probability of carcinogenic risk (dimensionless)
CDI= chronic daily intake (mg/kg.day)
SF= carcinogenic slop factor (kg.day/mg)

Regulators generally presume that a one-in-one million risk of cancer from life-long exposure to a hazardous chemical is an "acceptable risk" level over a 70-year lifetime.

To account for multiple substances in one route ,EPA sums the risk for each contaminants in medium:

$$Risk_T = \sum Risk_i \quad \text{……..(4)}$$

For multiple routes

$$\text{Total exposure risk} = \sum Risk_{ij} \quad \text{…… (5)}$$

Where:
i = the compounds and j= medium (route)
In alike manner, the hazard index multiple substances in one route is estimate as :

$$HI_T = \sum HI_i \quad \text{…….. (6)}$$

3.Microbial Risk Assessment

Microbial risk assessment hazard identification refers to the presence of micro-organisms and/or their toxins associated with a specific illness or deterioration of the same. Therefore, the question is: Does the hazard exist? To reply to it we need to look for information about pathogens, either in fact or potential, through clinical and epidemiological studies of microbial characterization and studies of the ecology of the illnesses. This information is of relevance at this stage of the study in order to assess if a particular etiological agent, here called a hazard, produces some health threat **(Razzolini, and Nardocci, 2008).**

Microbial quality of drinking-water includes testing for Escherichia coli as an indicator of faecal pollution. E. coli provides conclusive evidence of recent faecal pollution and should not be present in drinking-water. In practice, testing for thermotolerant coliform bacteria can be an acceptable alternative in many circumstances. While E. coli is a useful indicator, it has limitations. Enteric viruses and protozoa are more resistant to disinfection; consequently, the absence of E. coli will not necessarily indicate freedom from these organisms. Under certain circumstances, it may be desirable to include more resistant microorganisms, such as bacteriophages and/or bacterial spores. Such circumstances could include the use of source water known to be contaminated with enteric viruses and parasites or high levels of viral and parasitic diseases in the community **(WHO 2006).**

4.Data Collection and Data Measured:

4-1 Available Data

Data concerning raw and treated water quality parameters were collected from (Babylon Water Directorate) and (Babylon Environmental Directorate) for the period extened from January 2008 to December 2009.

4-2 Trace Elements Concentrations

The concentrations of trace elements (Cu, Zn, Hg, and Pb) for raw water of Shatt Al-Hilla river at six locations, and treated water for (Al-Hilla Al-Kadeem and Al-Hilla Al-Jadeed treatment plants) were adopted from pervious study of Jalil, 2009.

4-3 Data Measured

In order to examine the potential for public health risk associated with intrusion of contaminants into water supply distribution system, and because of the lack of available data concerning physical, chemical, and biological of water quality in distribution network the water quality parameters in households were tested .

Samples were collected from two households tap water in Babylon governorate. The first located in Al-Hilla city at Al-Eskan secter, and the second located at Al-Hashimeya city. The water quality parameters tested in these locations include : turbidity, pH, sulfate (SO4), nitrate (NO3), temperature(T), Chlorine (free) , E.coli, and coliform bacteria. Also the concentration of elements Arsenic (As) and chromium (Cr) were tested too. The standard methods for examination of water and waste water (APHA, 1998) were employed for all water quality measurements. Samples of this study were collected and analyzed for a period extended eight months starting from December 2009 until November 2010.

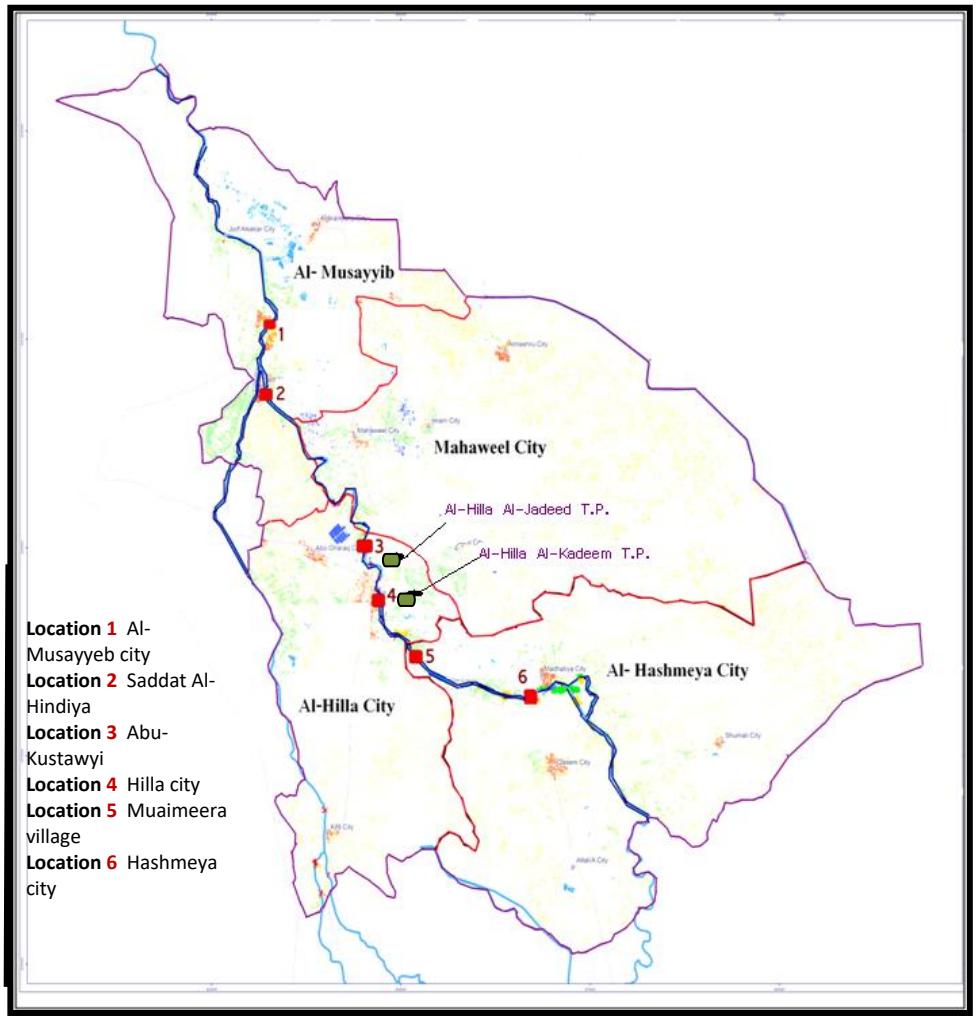

Fig.(1): Map of the studying area

5.Calculations and results

1- Chemical Risk Assessment

Standard values for use in the intake equation are shown in table (1) . Exposure to contaminants in raw water (Shatt Al-Hilla), treated and tap water were calculated by using

Equ. (1).While the HI for noncacinogenic chemicals in water was calculated by using Equ.(2) and risk for carcinogenic chemicals was calculated by using Equ.(3) .

Table (2) shows the results of the ingestion intake (I) and the hazard index (HI) for noncacinogenic chemicals in raw and treated water. While table (3) shows the results of the ingestion intake and risk for carcinogenic chemicals in raw, treated, and tap water.

Table (1): EPA Recommended values for estimating intake

Parameter	Standard value	
	Adult	Child (< 1.5 year)
Average body weight (kg)	70	10
Ingestion rate (L/day)	2	1
Exposure duration (carcinogenic effect)(year)	70	70
Exposure duration (noncarcinogenic effect)	30	30
exposure frequency (day/year)	365	365

Table (2): Results of intake and hazard index for noncarcinogenic chemicals in raw and treated water

Location	Contaminant	Concentration (mg/L) aver.	*I* (mg/kg.day)		Oral RfD (mg/kg.day)	*HI**	
			Adult	Child		Adult	Child
Location1	Hg	0.0018	5.1×10^{-5}	1.8×10^{-4}	0.0003	0.17	0.6
	Cd	0.0036	1×10^{-4}	3.6×10^{-4}	0.0005	0.2	0.72
	Cu	0.047	1.3×10^{-3}	4.7×10^{-3}	0.0371	0.04	0.13
	Zn	0.050	1.4×10^{-3}	5×10^{-3}	0.3	0.005	0.017
	HI_T					0.415	1.47
Location2	Hg	0.0012	3.4×10^{-5}	1.2×10^{-4}	0.0003	0.11	0.4
	Cd	0.0038	1.1×10^{-4}	3.8×10^{-4}	0.0005	0.22	0.76
	Cu	0.047	1.3×10^{-3}	4.7×10^{-3}	0.0371	0.04	0.13
	Zn	0.048	1.4×10^{-3}	4.8×10^{-3}	0.3	0.005	0.016
	HI_T					0.375	1.31
Continued: **Location3**	Hg	0.0015	4.3×10^{-5}	1.5×10^{-4}	0.0003	0.14	0.5
	Cd	0.0035	1×10^{-4}	3.5×10^{-4}	0.0005	0.2	0.7
	Cu	0.051	1.5×10^{-3}	5.1×10^{-3}	0.0371	0.04	0.14
	Zn	0.054	1.5×10^{-3}	5.4×10^{-3}	0.3	0.005	0.02
	HI_T					0.385	1.36
Location4	Hg	0.0014	4×10^{-5}	1.4×10^{-4}	0.0003	0.13	0.47
	Cd	0.0033	9.4×10^{-5}	3.3×10^{-4}	0.0005	0.19	0.66
	Cu	0.050	1.4×10^{-3}	5×10^{-3}	0.0371	0.04	0.13
	Zn	0.057	1.6×10^{-3}	5.7×10^{-3}	0.3	0.005	0.019
	HI_T					0.365	1.279
Location5	Hg	0.0016	4.6×10^{-5}	1.6×10^{-4}	0.0003	0.15	0.53
	Cd	0.0039	1.1×10^{-4}	3.9×10^{-4}	0.0005	0.22	0.78
	Cu	0.051	1.5×10^{-3}	5.1×10^{-3}	0.0371	0.04	0.14
	Zn	0.050	1.4×10^{-3}	5×10^{-3}	0.3	0.005	0.02
	HI_T					0.415	1.47
Location6	Hg	0.0015	4.3×10^{-5}	1.5×10^{-4}	0.0003	0.14	0.5
	Cd	0.0036	1×10^{-4}	3.6×10^{-4}	0.0005	0.20	0.72

	Cu	0.049	1.4×10^{-3}	4.9×10^{-3}	0.0371	0.04	0.13
	Zn	0.053	1.5×10^{-3}	5.3×10^{-3}	0.3	0.005	0.02
	HI_T					0.385	1.37
Al-Hilla Al-Jadeed treatment plant	Hg	0.00099	2.8×10^{-5}	9.9×10^{-5}	0.0003	0.093	0.33
	Cd	0.0026	7.4×10^{-5}	2.6×10^{-4}	0.0005	0.15	0.52
	Cu	0.040	1.1×10^{-3}	4×10^{-3}	0.0371	0.030	0.11
	Zn	0.051	1.5×10^{-3}	5.1×10^{-3}	0.3	0.005	0.017
	NO_3	1.55	4.4×10^{-2}	0.155	1.6	0.028	0.097
	HI_T					0.306	1.074
Al-Hilla Al-Kadeem treatment plant	Hg	0.00098	2.8×10^{-5}	9.8×10^{-5}	0.0003	0.093	0.32
	Cd	0.0028	8×10^{-5}	2.8×10^{-4}	0.0005	0.16	0.56
	Cu	0.039	1.1×10^{-3}	3.9×10^{-3}	0.0371	0.030	0.11
	Zn	0.053	1.5×10^{-3}	5.3×10^{-3}	0.3	0.005	0.018
	NO_3	1.79	5.6×10^{-2}	0.179	1.6	0.035	0.11
	HI_T					0.323	1.12

*** EPA allowable limits:**

If $\mathbf{HI}_T$ for multiple substances and pathways <1.0 and $\mathbf{Risk}_T$ for multiple substances and pathways < 1×10^{-6}: the risk acceptable else the risk unacceptable .

Table (3) :Results of intake and risk for carcinogenic chemicals in raw, treated, and tap water

Location	**Contaminant**	**Concentration (mg/L) aver.**	***I* (mg/kg.day)**		Oral SF $(mg/kg.day)^{-1}$	***Risk***	
			Adult	**Child**		**Adult**	**Child**
Location1	Pb	0.0048	1.4×10^{-4}	4.8×10^{-4}	0.00568	7.9×10^{-7}	2.7×10^{-6}
Location2	Pb	0.0048	1.4×10^{-4}	4.8×10^{-4}		7.9×10^{-7}	2.7×10^{-6}
Location3	Pb	0.0044	1.3×10^{-4}	4.4×10^{-4}		7.4×10^{-7}	2.5×10^{-6}
Location4	Pb	0.0047	1.3×10^{-4}	4.7×10^{-4}		7.4×10^{-7}	2.7×10^{-6}
Location5	Pb	0.0049	1.4×10^{-4}	4.9×10^{-4}		8×10^{-7}	2.8×10^{-6}
Location6	Pb	0.0044	1.3×10^{-4}	4.4×10^{-4}		7.4×10^{-7}	2.5×10^{-6}
Al-Hilla Al-Jadeed treatment plant	Pb	0.0033	9.4×10^{-5}	3.3×10^{-4}		5.3×10^{-7}	1.9×10^{-6}
Al-Hilla Al-Kadeem treatment plant	Pb	0.0035	1×10^{-4}	3.5×10^{-4}		5.7×10^{-7}	2×10^{-6}
Home/Al-Eskan /Al-Hilla City	As	0.053	1.5×10^{-3}	5.3×10^{-3}	1.5	2.3×10^{-3}	7.9×10^{-3}
	Cr	0.018	5.1×10^{-4}	1.8×10^{-4}	0.19	9.7×10^{-5}	3.4×10^{-4}
	$Risk_T$					**2.4×10^{-3}**	**8.2×10^{-3}**
Home/ AL-Hashimiya	As	0.064	1.83×10^{-3}	6.4×10^{-3}	1.5	2.7×10^{-3}	9.6×10^{-3}
	Cr	0.059	1.7×10^{-3}	5.9×10^{-3}	0.19	3.2×10^{-4}	1.1×10^{-3}
	$Risk_T$					**3.0×10^{-3}**	**1.1×10^{-2}**

2- Microbial Risk Assessment in Drinking Water

Risk assessment for E.coli in treated and distributed water , was calculated by using equations below: **(Fewtrell and Bartram, 2001)**.

$$PI(\text{infection/day}) = 1 - \left[1 + \frac{d}{N_{50}}\right]^{-\alpha} \quad \text{…….. (7)}$$

PI (infection/year) = (PI (infection/day)) ×365 …… (8)

Where:

N50= median infectious dose

α= slope parameter

d=V×C
d= Ingestion dose
V=Consumption of drinking water (2 L/day).
C= Exposure by drinking water, organisms per liter .

Illness is conditional on infection, and the probability of becoming ill can be written as: **(Navier et al., 2006).**

P (ill/dose) = PI (infection/year) × P (ill/infection) …….. (9)

Where P (ill/infection) is the infectivity rate of the germ. The value of P(ill/infection) given infection for diarrheal disease assumed equal to 0.25 **(Howard and Pedley, 2003).**

P (ill/infection) = 0.25

Table (4) show the results of risk assessment of E.coli in treated and tap water . The values of parameter using in the Equ.(7) are: **(Fewtrell and Bartram, 2001).**

$\mathbf{N_{50}}= 8.6\times10^{7}$
$\boldsymbol{\alpha} = 0.1778$
V= 2 L/day

Table(4): Risk assessment of E.coli in treated and tap water

location	***E.coli*** **ceel/L**	***PI*** (infection/day)	***PI*** ** (infection/year)	**P** (ill/infection)	**P** (ill/dose)**
Al-Hilla Al-Kadeem treatment plant	0	0	0	0.25	0
Al-Hilla Al-Jadeed treatment plant	0	0	0	0.25	0
Home/Al-Karama/ Hilla	6	2.4×10^{-8}	9.1×10^{-6}	0.25	2.3×10^{-6}
Home /Al-Akrameen/hilla	0	0	0	0.25	0
Home/Nader/Hilla	0	0	0	0.25	0
Home/Al-Eskan /Hilla	11.5	4.7×10^{-8}	1.7×10^{-5}	0.25	4.3×10^{-6}
Barnoon treatment plant	4	1.6×10^{-8}	6.0×10^{-6}	0.25	1.5×10^{-6}
Fedek restaurant/ Atayege region	59.5	2.5×10^{-7}	8.9×10^{-5}	0.25	2.2×10^{-5}

**** EPA allowable limits**:

If ***PI*** (infection/day) and **P** (ill/dose) $< 1\times10^{-6}$: the risk acceptable else the risk unacceptable .

6.Stochastic Approach

In this study the statistical models which described the relations between the water quality parameters and number of infections of each disease were established . Data used in the statistical models consist of monthly means of water quality parameters and the monthly mean of number infections for cholera, diarrhea, typhoid and hepatitis diseas. The statistical model for each disease was generated to raw water (Shatt Al-Hilla river); treated water, and distributed tap water in Al-Hilla city.

6-1 Regression Models

Stepwise multiple linear regression models in three forms of transformation were used for each model to investigate which form give the best fitting of data. The regression analysis was done by using (SPSS) program version (17).

Standard linear model was found to be the most suitable for all regression models. The best fitting of data gives the best model selected on the basis of the higher coefficient of determination (R^2) value and smaller value of the standard error

of the estimate. Also the analysis of variance (ANOVA) was used to determine the significant difference at the 0.05 level.

In all models , the number of infections for each disease (cholera, diarrhea, typhoid, and hepatitis) were taken as dependent variable (y), and the parameters of water quality at raw , treated, and distributed tap water were taken as independent variables . Table (5) shows these independent variables.

Table (5): Description of independent variables

independent variable	Description
X1	*Turbidity (NTU)*
X2	*Hydrogen ion concentration (pH)*
X3	*Nitrate (NO_3 , mg/L)*
X4	*Total dissolved solids, (TDS, mg/L)*
X5	*Chloride, (CL^-, mg/L)*
X6	*Phosphate (PO_4 ,mg/L)*
X7	*Total hardness (T.H, mg/L)*
X8	*Sulphate, (SO_4, mg/L)*
X9	*Potassium (K, mg/L)*
X10	*Temperature (T,C^o)*
X11	*Alkalinity (Alk., mg/L)*
X12	*Chlorine(free) (Cl , mg/L)*
X13	*E.coli(ceel/L)*

6-2 Statistical Analysis Results

The results of statistical analysis can be seen in table (6). This table shows the summary of each model for raw, treated, and distributed tap water in Al-Hilla city. Tables (7) to (17) shows correlation matrix , while tables (18) to (28) shows the ANOVA analysis for raw, treated, and distributed tap water.

Table (6): Statistical analysis results.

	Period Date	*Depended variable(y)*	*model*	*Stand. Err.*	R^2	*Correlation matrix Table*	*ANOVA Table*
Raw water (Shaat Al-Hilla river)	2008-2009	**Number of infection for cholera disease**	**0.28*x1-1.57*x2+1.02*x3-0.11*x4+41.96*x6+0.01*x7+0.07*x8+0.32*x10+0.01*x11-4.62**	**5.057**	**0.614**	(7)	(18)
		Number of infection for diarrhea disease	**1.75*x1+10.19*x2+8.73*x3+0.24*x4-0.503*x5+35.79*x6 + 555.49**	**8.857**	**0.911**	(8)	(19)
		Number of infection for typhoid disease	**0.19*x1+0.46*x2+0.63*x3 + 18.56*x6+0.004*x7-0.01*x8-0.16*x9+0.01*x11+47.25**	**1.249**	**0.860**	(9)	(20)
		Number of infection for hepatitis disease	**0.11*x1+0.30*x2+0.15* x3 +0.001* x4-0.01*x5+1.48*x6-0.02*x7+0.01*x8-3.46**	**0.601**	**0.839**	(10)	(21)
Treated water	2008-2009	**Number of infection for cholera disease**	**0.47*x1+6.32*x2+1.68*x3+0.008*x4+5.58*x6-0.03*x7-0.05*x8+0.10*x10+0.45*x11-82.04**	**4.390**	**0.628**	(11)	(22)
		Number of infection for diarrhea disease	**2.98*x1- 9.80*x2-8.31*x3+0.08*x4 - 159.87*x6+0.25*x7+0.27*x8+14.21*x12+578.22**	**9.411**	**0.866**	(12)	(23)
		Number of infection for typhoid disease	**0.38*x1- 1.56 *x2+0.97*x3+0.008*x4+ 24.34*x6+0.02*x7-0.04*x8 +0.20*x10+2.21*x12 +61.12**	**1.738**	**0.810**	(13)	(24)
		Number of infection for hepatitis disease	**0.43*x1- 1.30*x2 -0.005*x4+ 35.87*x6+0.02*x7- 0.03*x8+0.13*x10- 0.05*x11+1.38*x12 +60.81**	**0.675**	**0.802**	(14)	(25)

Distributed water	2008-2009	**Number of infection for diarrhea disease**	**0.652*x1- 9.84*x2+10.58*x3+1.73*x8 + 0.53*x12+ 2.63*x13 +71.21**	**3.810**	**0.775**	(15)	(26)
		Number of infection for typhoid disease	**- 0.117*x1 +0.965*x3- 0.082*x10+1.56*x12+0.081*x13+99.790**	**1.217**	**0.755**	(16)	(27)
		Number of infection for hepatitis disease	**0.06*x1 – 1.04*x3 + 0.07*x10- 1.00*x12+0.03*x13+2.30**	**0.718**	**0.865**	(17)	(28)

Table (7) : Correlation matrix for cholera disease and quality parameters of raw water (Shatt Al-Hilla river

Parameter	y
X1	0.464
X2	0.263
X3	0.243
X4	0.114
X6	0.470
X7	0.136
X8	0.207
X10	0.483
y	1

Table (8) : Correlation matrix for diarrhea disease and quality parameters of raw water (Shatt Al-Hilla river)

Parameter	y
X1	0.760
X2	0.527
X3	0.242
X4	0.467
X5	0.267
X6	0.272
y	1

Table (9) : Correlation matrix for typhoid disease and quality parameters of raw water (Shatt Al-Hilla river)

Parameter	y
X1	0.785
X2	0.429
X3	0.364
X6	0.520
X7	0.276
X8	0.112
X9	0.439
X11	0.279
y	1

Table (10) : Correlation matrix for hepatitis disease and quality parameters of raw water (Shatt Al-Hilla river)

Parameter	y
X1	0.882
X2	0.509
X3	0.258
X4	0.025
X5	0.252
X6	0.200
X7	0.229
X8	0.253
v	1

Table (11) : Correlation matrix for cholera disease and quality parameters of treated water(Hilla city)

Parameter	y
X1	0.473
X2	0.293
X3	0.281
X4	0.058
X7	0.138
X8	0.362
X10	0.415
X11	0.633
y	1

Table (12) : Correlation matrix for diarrhea disease and quality parameters of treated water (Hilla city)

Parameter	y
X1	0.567
X2	0.251
X3	0.363
X4	0.421
X6	0.340
X7	0.406
X8	0.685
X12	0.710
y	1

Table (13) : Correlation matrix for typhoid disease and quality parameters of treated water (Hilla city)

Parameter	y
X1	0.607
X2	0.247
X3	0.395
X4	0.207
X6	0.753
X7	0.559
X8	0.331
X10	0.289
X12	0.413
y	1

Table (14) : Correlation matrix for hepatitis disease and quality parameters of treated water (Hilla city)

Parameter	y
X1	0.607
X2	0.247
X4	0.207
X6	0.753
X7	0.559
X8	0.331
X10	0.330
X11	0.194
X12	0.413
y	1

Table (15) : Correlation matrix for diarrhea disease and quality parameters of distributed water (Hilla city)

Parameter	y
X1	0.743
X2	0.153
X3	0.589
X8	0.140
X12	0.638
X13	0.724
y	1

Table (16) : Correlation matrix for typhoid disease and quality parameters of distributed water (Hilla city)

Parameter	y
X1	0.658
X3	0.488
X10	0.396
X12	0.778
X13	0.688
y	1

Table (17) : Correlation matrix for hepatitis disease and quality parameters of distributed water (Hilla city)

Parameter	y
X1	0.573
X3	-0.065
X10	o.533
X12	-0.009
X13	0.792
y	1

Table (18): ANOVA analysis of cholera disease of raw water (Shatt Al-Hilla river)

Source	Sum of Squares	DF	Mean Square	F	Sig.
Regression	567.946	8	70.993	2.969	0.033
Residual	358.679	15	23.912		
Total	926.625	23			

Table (19): ANOVA analysis of diarrhea disease of raw water (Shatt Al-Hilla river)

Source	Sum of Squares	DF	Mean Square	F	Sig.
Regression	13490.220	6	2248.370	28.658	0.000
Residual	1333.738	17	78.455		
Total	14823.958	23			

Table (20): ANOVA analysis of typhoid disease of raw water (Shatt Al-Hilla river)

Source	Sum of Squares	DF	Mean Square	F	Sig.
Regression	143.528	8	17.941	11.486	0.000
Residual	23.430	15	1.562		
Total	166.958	23			

Table (21): ANOVA analysis of hepatitis disease of raw water (Shatt Al-Hilla river)

Source	Sum of Squares	DF	Mean Square	F	Sig.
Regression	28.959	8	3.620	9.799	0.000
Residual	5.541	15	0.369		
Total	34.500	23			

Table (22): ANOVA analysis of cholera disease of treated water (Hilla city)

Source	*Sum of Squares*	*DF*	*Mean Square*	*F*	*Sig.*
Regression	*486.489*	*8*	*60.811*	*3.155*	*0.026*
Residual	*289.136*	*15*	*19.276*		
Total	*775.625*	*23*			

Source	Sum of Squares	DF	Mean Square	F	Sig.
Regression	8604.841	8	1075.605	12.145	0.000
Residual	1328.492	15	88.566		
Total	9933.333	23			

Table (23): ANOVA analysis of diarrhea disease of treated water (Hilla city)

Source	Sum of Squares	DF	Mean Square	F	Sig.
Regression	183.955	10	18.395	6.131	0.002
Residual	39.004	13	3.000		
Total	222.958	23			

Table (24): ANOVA analysis of typhoid disease of treated water (Hilla city)

Source	Sum of Squares	DF	Mean Square	F	Sig.
Regression	178.903	9	19.878	6.317	0.001
Residual	44.055	14	3.147		
Total	222.985	23			

Table (25): ANOVA analysis of hepatitis disease of treated water (Hilla city)

Source	Sum of Squares	DF	Mean Square	F	Sig.
Regression	178.903	9	19.878	6.317	0.001
Residual	44.055	14	3.147		
Total	222.985	23			

Table (26): ANOVA analysis of diarrhea disease of distributed water (Al-Hilla city)

Source	Sum of Squares	DF	Mean Square	F	Sig.
Regression	15637.827	6	2606.304	4.597	0.026
Residual	4535.507	8	566.938		
Total	20173.333	14			

Table (27): ANOVA analysis of typhoid disease of distributed water (Al- Hilla city)

Source	Sum of Squares	DF	Mean Square	F	Sig.
Regression	41.068	5	8.214	5.545	0.013
Residual	13.332	9	1.481		
Total	54.400	14			

Table (28): ANOVA analysis of hepatitis disease of distributed water (Al- Hilla city)

Source	Sum of Squares	DF	Mean Square	F	Sig.
Regression	19.904	5	3.981	7.715	0.014
Residual	3.096	6	0.516		
Total	23.000	11			

7. Conclusions

From this study the following conclusions are obtained:

1. Results show that the total noncarcinogenic hazard index (HI_T) in raw and treated water were acceptable for adult and not acceptable for child.
2. The carcinogenic risk caused by chronic daily ingestion intakes for lead in raw and treated water at all locations were not acceptable risk especially for children.
3. The total carcinogenic risk ($Risk_T$) caused by chronic daily ingestion intakes for (As &Cr) at tap water in Al-Hilla city were observed high risk for adult and children respectively and that mean there are possible adverse health effects for human health.
4. For microbial risk assessment, an average annual infection PI (infection/ year) caused by E.coli in drinking water and risk of diarrheal disease given infection caused by E. coli in drinking water (average P (ill/dose)) tends to become significant , spatially at tap water because the deterioration of water quality in the distribution system.
5. The statistical results showed a good positive correlation between number of infection of cholera, diarrhea, typhoid and hepatitis disease with water quality parameters at raw, treated , and distributed water.
6. The analysis of variance (ANOVA) showed significant difference between the independent and dependent variables at the 0.05 level of significance.

8. References

- **Beck, N., (2006),** ″ Proposed Risk Assessment Bulletin ″ , Office of Information and Regulatory Affairs, Washington .
- **Boyd, D., R. , (2006),** ″ The Water We Drink: An International Comparison of Drinking Water Standards and Guidelines″ Vancouver, BC, Canada V6K 4S2 .
- **Davis, M. L. and Masten, S.J., (2004),** ″ principles of Environmental of Engineering and Science″, Michigan state university-East Lansing , book .
- **Davies, J. C., (1996),** ″Comparing Environmental Risks: Tools for Setting Government Priorities″, Northeast Center for Comparative Risk, South Royalton.
- **EPA, (2000),** ″ A Guide to Health Risk Assessment″, California EPA, Office of Environmental Health Hazard Assessment, P.O. Box 4010 Sacramento, CA 95812-4010, (916) 324-7572, http:// www. oehha.ca.gov.
- **Fewtrell, L. and Bartram, J., (2001),** ″water Quality: Guidelines, Standards and Health″ Published by IWA Publishing, London, UK**.** ISBN: 1 900222 28 0
- **Jalil, A., (2009),** ″Evaluation of Selected Trace Elements in Shatt Al-Hilla River″, M. Sc. Thesis, College of Engineering, Civil Engineering, University of Babylon.
- **Howard, G. and Pedley S., (2003),** ″ Quantitative Microbial Risk Assessment for piped Water Supplies in Uganda″ , Robens Center for Public and Environmental Health, University of Surrey.
- **Navier, D., Laroche, L. and Hartemann, P. (2006),** ″ Waterborne Microbial Risk Assessment″, Grenoble University Hospital, 38700 La Trochee, France, http://www.biomedcentral.com/1471- 2458/6/122.
- **Razzolini, M. T. and Adelaide, C. ,(2008),** ″ Microbial Risk Assessment :Stages and Application the Evaluating of Water Quality″, AJournal on Integrated Management of Occupational Health and the Environmental , v.1, n.2, Art 3, , http://www.interfacehs.sp.senac.br/en/articles.asp.
- **Sadiq, R., Kleiner , Y. and Rajani , B., (2007),** ″ Water Quality Failure in Distribution Network- Risk Analysis Using Fuzzy Logic and Evidential Reasoning ″, Journal of Water Supply Research and Technology , V. 27, No. 5, PP 1381-1394, NRCC-50083.
- **WHO, (2006),** ″ Guidelines for Drinking-water Quality″ 3rd Edition , Vol. 1, Recommendations , Geneva