International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.12 No.04, pp 73-86, 2019

Proposed Water Quality Management System for Euphrates River (A Case Study in Babylon Province)

Nabaa Shakir Hadi

Environmental Engineering Dep, Engineering College, Babylon University, Iraq

Abstract : The approach presented in the study concentrates specifically on aspects related to water quality,with special emphasis on the conditions typically prevailing in Iraq (Babylon Province). The intention is to demonstrate an approach to water quality indices and water pollution control by using expert system component in an intelligent front end. An artificial intelligence (Al) program was built up to develop the water quality management system (WQMS) which includes two parts

(1) Water quality index system WQIS
(2) Water pollution control system WPCS

WQIS developed four independent water quality indices for use in the operational management of Euphrates River as follows:

(a) General Water Quality Index (GWQI)
(b) Specific Use-Related indices consist of:
(i) Potable Water Supply Index PWSI
(ii) Industrial Water Quality Index IWQI
(iii) Irrigation Water Quality Index RWQI

The data determinant used in Babylon Province the system as monthly mean values for a period of one yearfrom Oct 2014 to Sep 2015 for three sampling sites along Euphrates River (Mussaib, Hindiya, Kifil) and five sampling sites along Shatt Al Hilla (Hindiya, Hilla Center, Hashimya, Shoumaly, Thalya). The overall determinants used in the program are, (T, Tur, TH, PH, EC, DO_2, CL, SO_4, NO_3, PO_4, TDS and SAR).Ten important formulas were used in the program. The user can choose any one of them to develop the final water quality index score.

The system reflects water use thus providing information to operational management for specific water use.The remedial and pollution preventive measures were proposed for enhancingEuphrates River water quality.

The water pollution control system "WPCS" comprises the water pollution control elements and are categorized in three axes:

Axis one – Initial analyses of water quality problems.
Axis two – Establishing objectives for water pollution control.
Axis three – Derivation of management interventions, tools and instruments needed to fulfill the management objective.

Water quality experts in Iraq (Babylon Province) evaluated sixty-two elements of water pollution control processes.WPCS analyzed the responses weighted mean for elements of water pollution control processes in IraqBabylon Province) depending upon the "Central Limit Theorem" and determined the faults in the water pollution control system in Iraq and suggested the corrective actions and arranging the corrective actions into three types.

(1) Actions supporting the development of an enabling environment.
(2) Actions supporting development of an institutional framework.
(3) Action enhancing planning and prioritization capabilities.
In the light of results,the corrective actions needed to control the river pollution in Iraq were suggested.Finallythe conclusion on the evaluation of "WQMS " indicated its efficiency toclassify theriver waterquality and to diagnose the faults and the corrective actions for the water pollution control system in Iraq.
Keywords : Water quality management , River pollution , Babylon Province.

DOI= http://dx.doi.org/10.20902/IJCTR.2019.120412

Introduction

Deterioration of water quality within the world has become a problem in recent years. This is due, in part, to increased water consumption which, in turn, results in increased waste production resulting in the degradation of water quality in both surface and ground water resources. Today there is an increasing awareness of and concern about water pollution all over the world and new approaches towards achieving sustainable explication of water resources have been developed internationally. It is widely agreed that a properly developed policy frame work is a key element in the sound management of water resources. Euphrates River has a large importance for Iraqi environment researchers because of the detrimental effect of pollutants resulting from treated and untreated domestic sewage, treated and untreated industrial wastewater and agricultural pollutants. The main source of water for this river are rain water, stored water as lake and reservoirs. Shatt Al-Hilla river is branch of Euphrates river at Al-Hindiya Barrage town, its length through Babylon province is about 104 Km[1].

Materials and Methods:

An Artificial intelligence (Al) program was written in a visual basic language and build up to develop an expert system embodying the searched knowledge related to each index. An expert system can be defined as "A class of computer programs that can device, analyze, categorize, diagnose, consult, design, explore, plan, present, retrieve, schedule, test and tutor"

Water Quality Index System

The program depended on three sampling sites along Euphrates river (Mussaib, Hindiya, Kifil) and five sampling sites along Shatt Al Hilla (Hindiya, Hilla Center, Hashimya, Shoumaly, Thalya).Data were collected from the period of one year from Oct 2014 to Sep 2015. These data represent (T, Tur, TH, PH, EC, DO_2, CL, SO_4, NO_3, PO_4, TDS and SAR). According to the various formulas which are used to calculate the water quality index, the following are the most important ones mentioned in the literature surveyed:

Cumulative Formulation:

This formula is expressed As

[2]: $$WQI = \left[\frac{\sum_{i=1}^{n} C_i . W_i}{\sum_{i=1}^{n} W_i}\right] M_1 . M_2 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (1)$$

Where:

WQI =water quality index.
C_i =the rating for the ith determined.
W_i =the weighting for the ith determined.
$M_1 . M_2$ =additional determined parameters.

n =number of determineds.

Arithmetic Weighted Formula:

This formula is given as[3]:

$$WQI = \sum_{i=1}^{n} q_i . w_i \dots\dots\dots\dots\dots\dots (2)$$

Where:

q_i =represents the rating for the ith determinant, and this value varies from (0-100).
w_i = represents the weighting for the ith determinant, and this varies from (0-1) and $\sum w_i = 1$.
n =represents the number of determinants.

Geometric Weighted Mean:

McClelland (1974) concluded the multiplicative weighed formula which later called the Geometric weighted mean and expressed as[4]:

$$WQI = \prod_{i=1}^{n} q_i^{wi} \dots\dots\dots\dots\dots\dots (3)$$

Geometric Mean Formula:

Brown (1970) suggested the geometric mean formula which is expressed as[3]:

$$WQI = \prod_{i=1}^{n} q_i^{1/n} \dots\dots\dots\dots\dots\dots (4)$$

Modified Arithmetic Weighted Formula:

The Scottish Development Department (SDD) suggested a modified arithmetic weighted formula whichis given by[5]:

$$WQS = \frac{1}{100} \sum_{i=1}^{n} (q . w_i)^2 \dots\dots\dots\dots\dots\dots (5)$$

Harmonic Mean Formula:

Stojda and Dojtido suggested the use the homogenous weighted formula to calculate the water quality index[6]:

$$WQI = \sqrt{\frac{1}{\sum_{i=1}^{n} \frac{w_i}{q_i^2}}} \dots\dots\dots\dots\dots\dots (6)$$

Harmonic Square Mean Formula:

Dojlido suggested to use the weighted homogenous formula to calculate the water quality index[7]:

$$WQI = \sqrt{\frac{1}{\sum_{i=1}^{n} \frac{1}{q_i^2}}} \dots\dots\dots\dots\dots\dots (7)$$

Geometric Mean as Sensitivity Function Formula:

Bahargava suggested the geometric mean formula expressed as[8]:

$$WQI = \left[\prod_{i=1}^{n} fi(P_i)\right]^{1/n} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (8)$$

Where $fi(P_i)$ the sensitivity function for each variable including the effect of variable weight concentration which is related to a certain activity and varies from (0-1).

Minimum Operator Formula:

Smith suggested another formula to calculate the water quality index and it was a minimum operator given by[9]:

$$WQI = min(I_1, I_2, I_3, \ldots\ldots\ldots\ldots\ldots. I_n) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (9)$$

Where I_n represents the arbitrary index for each determinant and its value varies from(0-100).

Maximum Operator Formula:

ESCWA organization has developed a water quality index depending on the maximum operator[10]:

$$WQI = max(I_1, I_2, I_3, \ldots\ldots\ldots\ldots\ldots. I_n) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (10)$$

Where I_n represents the arbitrary index for each determinant which results from dividing the determinant concentration by the maximum allowable concentration.

Water Pollution Control System

The approach presented in this study concentrates specificity on aspects related to water quality, with special emphases on the conditions typically prevailing in developing countries and countries in economic transition [11].

- **Water Pollution Control Element (WPCE)**

The water pollution control system comprises the elements and is categorized in three axes:

- Axis One – initial Analysis of water quality problems.
- Axis Two – Establishing objectives for water pollution control.
- Axis three– Derivation of management interventions, tools and instruments needed to fulfill the management objectives.

Table1:Experts Responses Weighted Mean For Elements of Water Pollution Control in Iraq.

Elements Number	Elements of Water Pollution Control	Responses Weighted Mean
	Axis One (Initial Analysis Of Water Quality Problems).	
	Identification Of Water Quality Problems:	
1	Water resources assessment.	6.30
2	Identifying priority areas, which need more detailed investigation to be carried out.	3.60
	Categorization Of Water Quality Problems:	
3	Water quality problems pertinent to a local community or national problems.	4.30
4	Categorization of water quality problems as "Impact Issues".	3.35
5	Categorization of water quality problems as "User Requirements ".	3.60
	Prioritization Of Water Quality Problems:	
6	Economic Impact.	5.60
7	Human Impact.	6.80

8	Impact of Ecosystem.	2.60
9	Geographical extant of Impact.	2.30
10	Duration of Impact.	1.70
	Axis Two(Establishing Objectives For Water Pollution Control).	
	Required Management Interventions:	
11	Policy making, Planning and Co-ordination.	5.60
12	Preparation, Adjustment of regulations.	6.30
13	Monitoring.	4.60
14	Enforcement of legislation.	4.30
15	Training and information dissemination.	3.35
	Long – Term Objectives:	
16	Identification of key function that will have to be performed in order to achieve reasonably effective water pollution control at administrative levels.	4.70
	Short – Term Strategy:	
17	The duration of the "short-term" is five years.	5.40
18	Maintaining monitoring activities at a central level but simultaneously upgrading the skills at the lower levels by meansof training activities and orientation programs.	3.40
19	Suitability of institutional framework.	3.60
20	Efficient of the number of staff.	2.66
21	Educational background of staff.	4.40
22	Recruit ability of relevant new staff.	4.33
23	Training staff and development of human resources.	3.70
24	Availability of financial resources.	3.30
	Axis Three(Management Tools And Instruments) **Regulations, Management Procedure And By-Laws:**	
25	Application of the local regulations.	6.30
26	Management procedures as asset of guidelines and codes of practice are used to solve problems and decision-making.	6.40
27	Application of the national regulation and management procedures taking account of regional variation in pollution and socio -economic conditions.	3.66
	Water Quality Standards:	
28	Application of Iraq standard No(417) for drinking water.	4.60
29	Iraqi standard No(417) for drinking water specifying the standard procedures for testing the potable water use.	2.70
30	Iraqi standard No(417) as a function of the level of economic and social development of a society.	2.30
31	Application of recreational water quality criteria.	1.30
32	Application of industrial water quality criteria.	2.70
33	Application of water quality criteria for irrigation.	2.33
34	Application of aquatic life criteria.	1.60
35	Application of domestic waste water criteria.	2.60
36	Application of industrial effluents criteria.	3.30
37	Adjusting the water quality standards to reflect the local economic and technology level.	2.35
	Economic Instruments:	
38	Water pricing policies.	2.00
39	Applying effluent charges to finance necessary measures for waste water collection and purification,and to provide financial incentives for reducing	2.40

	discharges of effluent.	
40	Making available tax reductions, grants or low interest loans.	3.35
41	Application of product charges like tax differentiation.	2.70
42	Application of penalties for failing to meet environmental standards.	4.70
	Monitoring System:	
43	Identification of decision and management information needs.	2.40
44	Assessment of capacity (economic and human) to maintain the monitoring system.	1.66
45	Proper design of the monitoring programmer and implementation of routines according to defined objectives.	2.66
46	Data collection.	3.00
47	Data handling, registration and presentation.	4.33
48	Data analysis.	3.70
	Water Quality Modeling Tools:	
49	Application of water quality modeling to quantify specific water quality problem and support rational management decisions.	2.66
50	Application of loading model.	7.60
51	Application of mass balance model.	7.00
52	Effect evaluation.	4.60
53	Application of ecological model.	3.70
	Environmental Impact Assessment and Cross-Sectorial Co-Ordination:	
54	Assessment of impacts as an integral part of an Environmental impact assessment (E.I.A.).	4.60
55	Assessment of the physical, biological and related economic and social impacts of proposed projects.	4.10
56	Non-governmental organizations and public participation are used to ease the implementation of projects and programs.	3.20
57	Water quality impact assessment provides approval or rejection ofwastewater discharge permit applications.	5.40
58	Water quality impact assessment provides inclusion of water quality consequences in the prioritization of development projects.	4.80
59	Water quality impact assessment provides modifications in the technical design of development projects with the aim of protecting water resources.	4.40
	Principles For Selecting And Combining Management Tools:	
60	Balance the input of resources against the severity of problem and available resources.	5.90
61	Ensure sustainability.	4.50
62	"Win-Win" solution.	2.90

The number of all elements are sixty two(shown in table 1). They were evaluated and analyzed by 30 expert who have high level of expertise in water quality management in Iraq and but in managerial position like head of departments, directors, or consultants.

The questionnaire list was prepared for elicitation of knowledge about the water pollution control in Iraq. It was designed to provide information about elements and processes of an action plan for water pollution control.

The experts were asked to select the suitable answers from one of five choices: always, often, sometime, rarely, and never. The answer is eliminated if the expert chooses(Do not know).Some of the questions were completed by the knowledge Engineer (The researcher) based on an interview with the expert.

The expert responses were weighed on a scale from "0" to "10" reflecting the importance of the water pollution control element.

The weights for the five answers choice are 9 , 7 , 5 , 3 , and 1 respectively.

❖ Statistical Analysis Of Water Pollution Control Elements

The special case of the "Central limit theorem" states that the distribution of the sample means approaches the normal distribution as sample size increases, and that the distribution of the sample mean from a normal population is always normal regardless of the sample size[12].

The normal distribution is one of the most important examples of a continuous probability distribution defined by the equation[13]:

$$\mu(\mu\,,\sigma^2) = f(y) = y = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}}(x-\mu)^2/\sigma^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

Where:

μ= Mean
σ=Standard deviation
σ^2=Variance
e =2.718 , π=3.14

++ The total area bounded by the curve and the X axis is one; hence the area under the curve between two ordinates X=a and X=b, where $a < b$, represents the probability that X lies between a and b, denoted by $Pr\{a < X < b\}$.

When the variable X is expressed in terms of standard units, then:

$$Z = (x-\mu)/\sigma \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Equation(4.1) is replaced by the co-called standard form:

$$y = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}} \quad z^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

In such a case , Z is normally distributed with mean zero and variance one.

According to this aspect, the diagnostic expert systemanalyses the responses weighted mean for elements of water pollution control processes in Iraq by determining the value of Z for each element. The negative means that, the element needs a corrective action with aspect to its probability which indicates the relative importance of the element.

❖ Corrective Action for Water Pollution Control System in Iraq.

A diagnostic expert system was built up to determine the faults in the water pollution control system in Iraq and suggest the corrective actions according to the statistical analysis employed. The knowledge acquired from literatures experts have been translate into ranges using " THREE " form that is formulate logical paths to reach results.

This activity entails recognizing the faults causes and arranging the corrective actions into three types

1. Actions supporting the development of an enabling environment.

i. Water resources policy and statute[14].

ii. Regulations and by-laws[15].

2. Actions supporting development of an institutional framework.

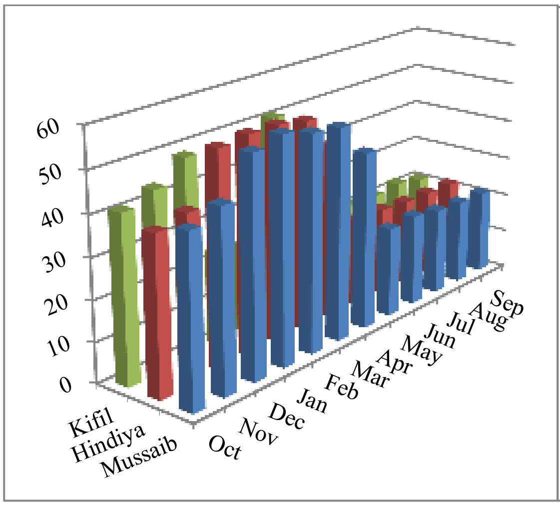
i. Management structure and capacity of building[16].

3. Actions enhancing planning and prioritization capabilities.

i. Information and monitoring systems.
ii. Enforcement mechanism.
iii. Management procedures.
iv. Public participation.
v. Resources pricing.
vi. Application of standards and criteria[17].

Results:

The value of water quality index (WQIS) by using "Geometric Mean as Sensitivity Function Formula" are shown in Euphrates river and Shatt Al Hilla Figures respectively (1),(2),(3), (4),(5),(6) ,(7) &(8). The figure as illustrate the fluctuation of water quality index scores along Euphrates river and Shatt Al Hilla throughout period of one year from Oct 2014 to Sep 2015. General water quality index scores represent a range of water quality and potential water use. Use related water quality index scores represent a range of water quality for specific uses industrial, irrigation, and Potable water supply.



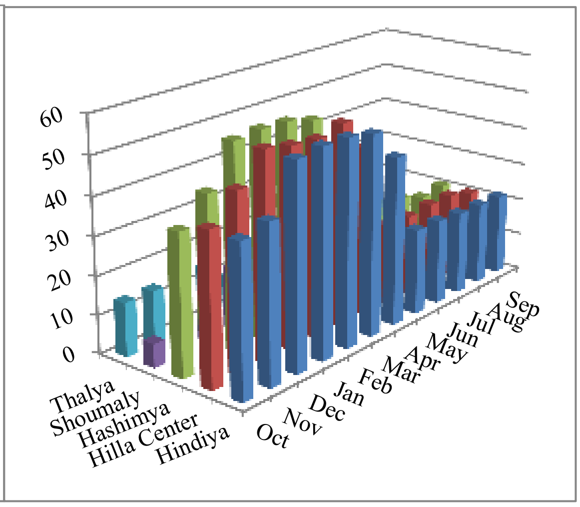
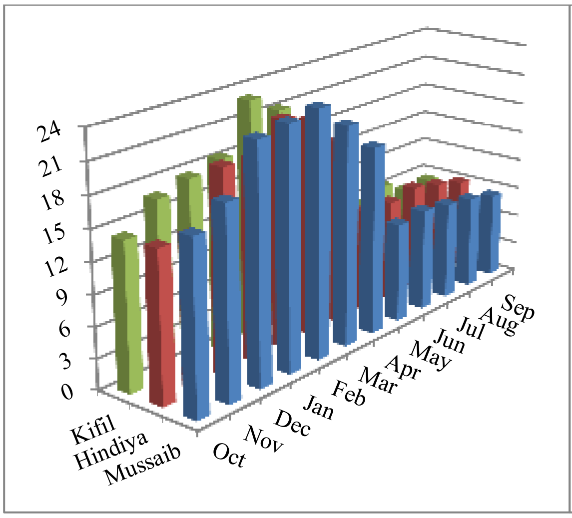


Fig1:General water quality index along Euphrates river in Babylonregion.

Fig2:General water quality index along Shatt Al Hilla in Babylon region.



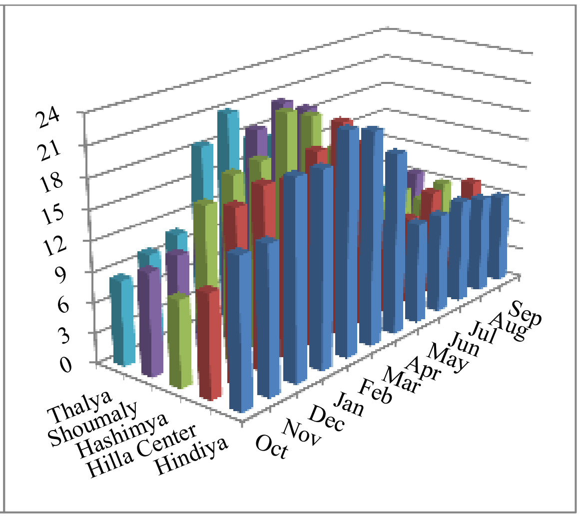


Fig3:Potable water quality index along Euphrates river in Babylon region

Fig4:Potable water quality index along Shatt Al Hilla in Babylon region

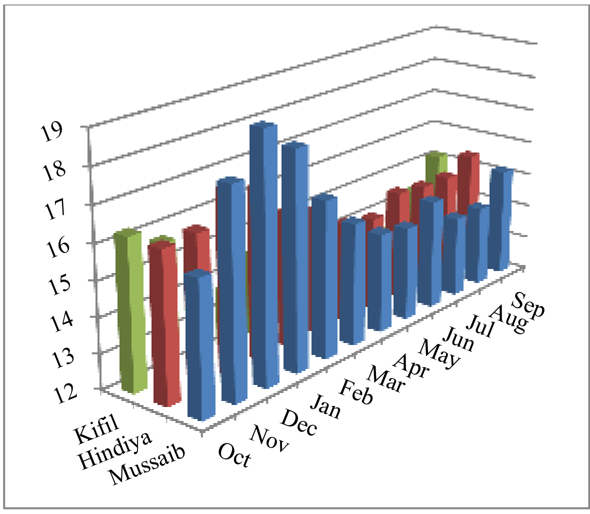


Fig5:Industrial water quality index along Euphrates river in Babylon region.

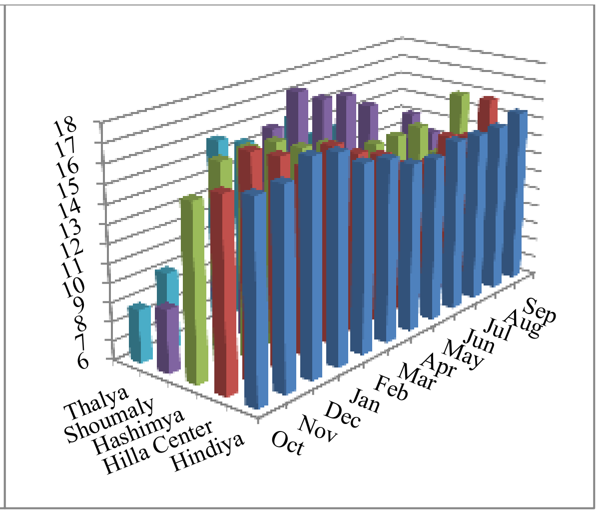


Fig6:Industrial water quality index along Shatt Al Hilla in Babylon region.

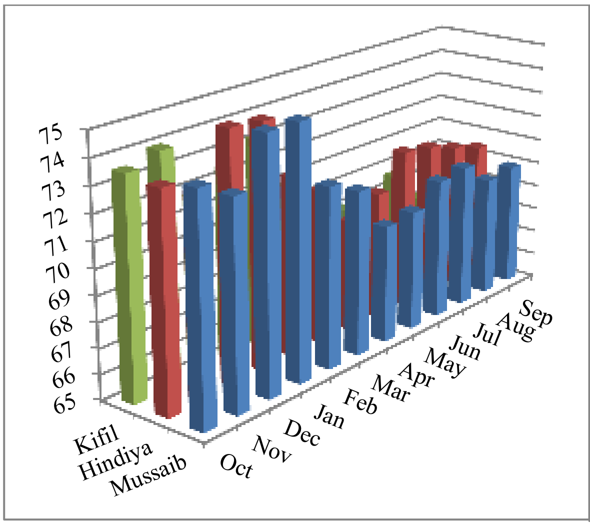


Fig7:Irrigation water quality index along Euphrates river in Babylon region.

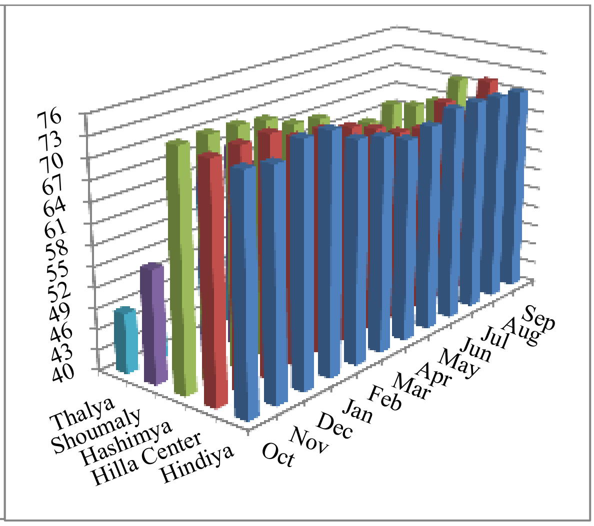


Fig8:Irrigation water quality index along Shatt Al Hilla in Babylon region.

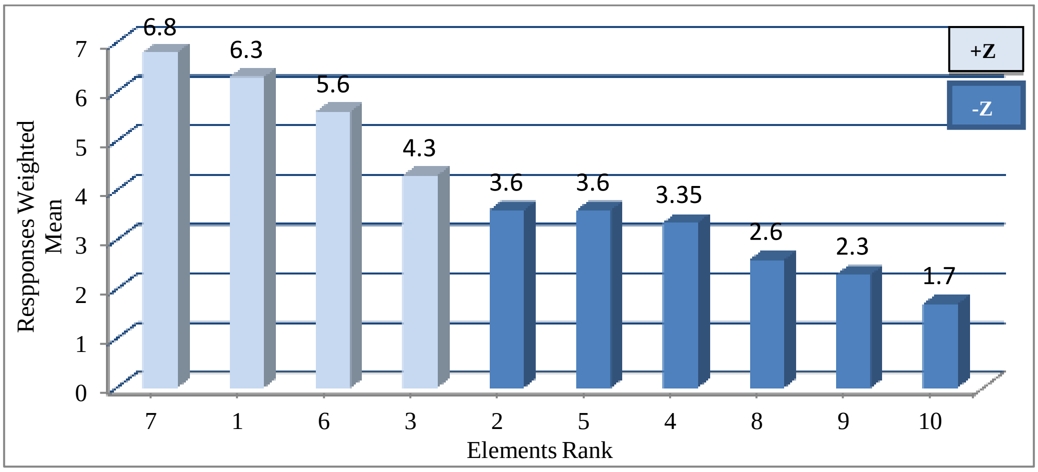


Fig9: Responses Weighted Mean and Elements Rank(Axis One).

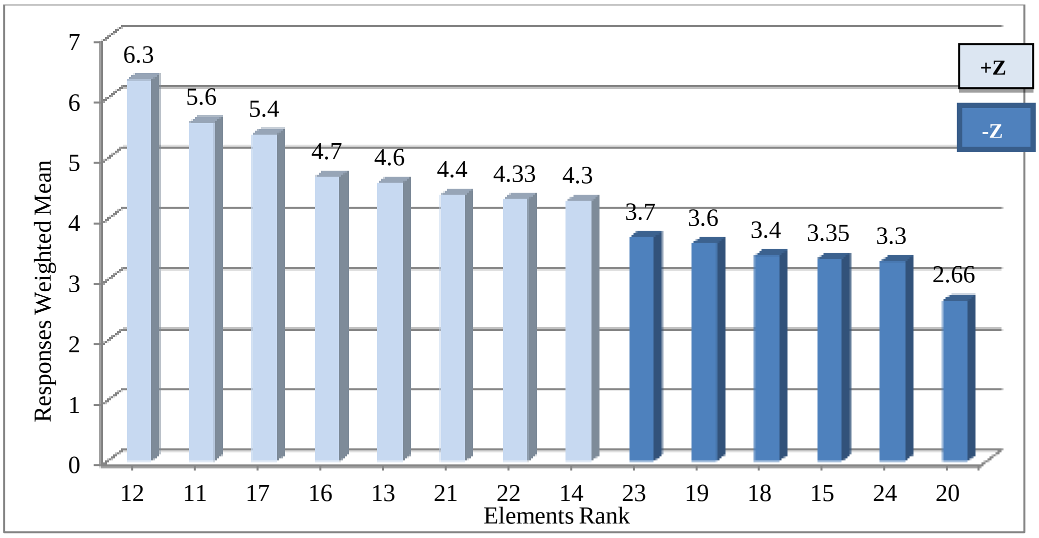


Fig10:Responses Weighted Mean and Elements Rank(Axis Two).

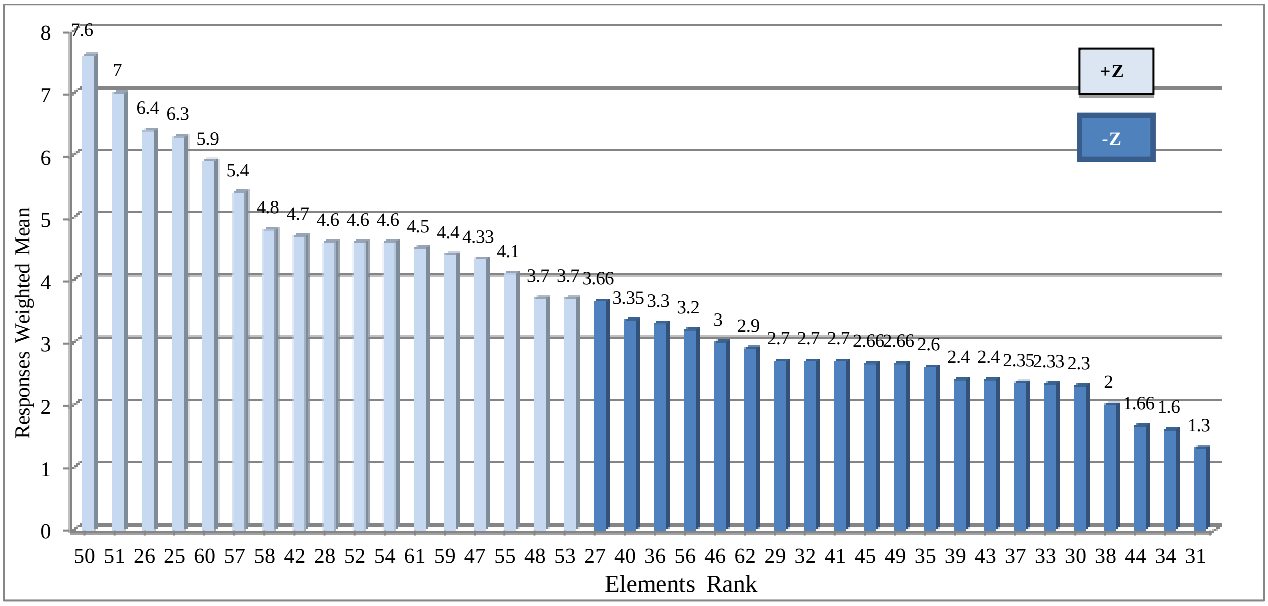


Fig11:Responses Weighted Mean and Elements Rank(Axis Three).

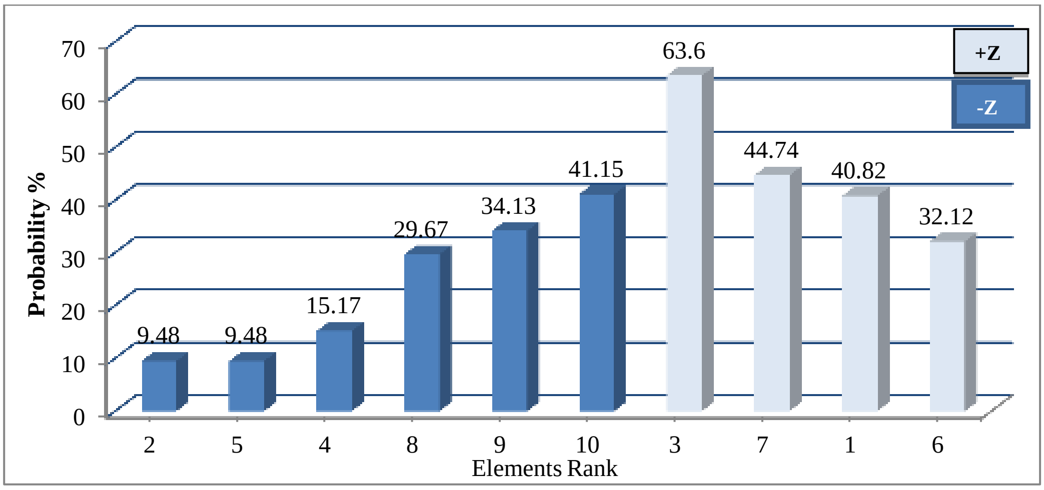


Fig12:The Probabilities and Elements Rank(Axis One).

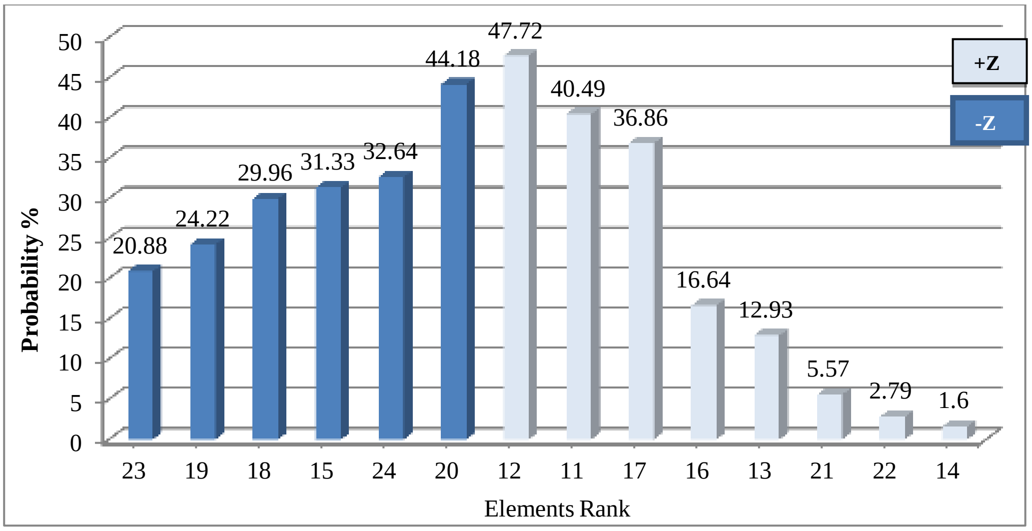


Fig13:The Probabilities and Elements Rank(Axis Two).

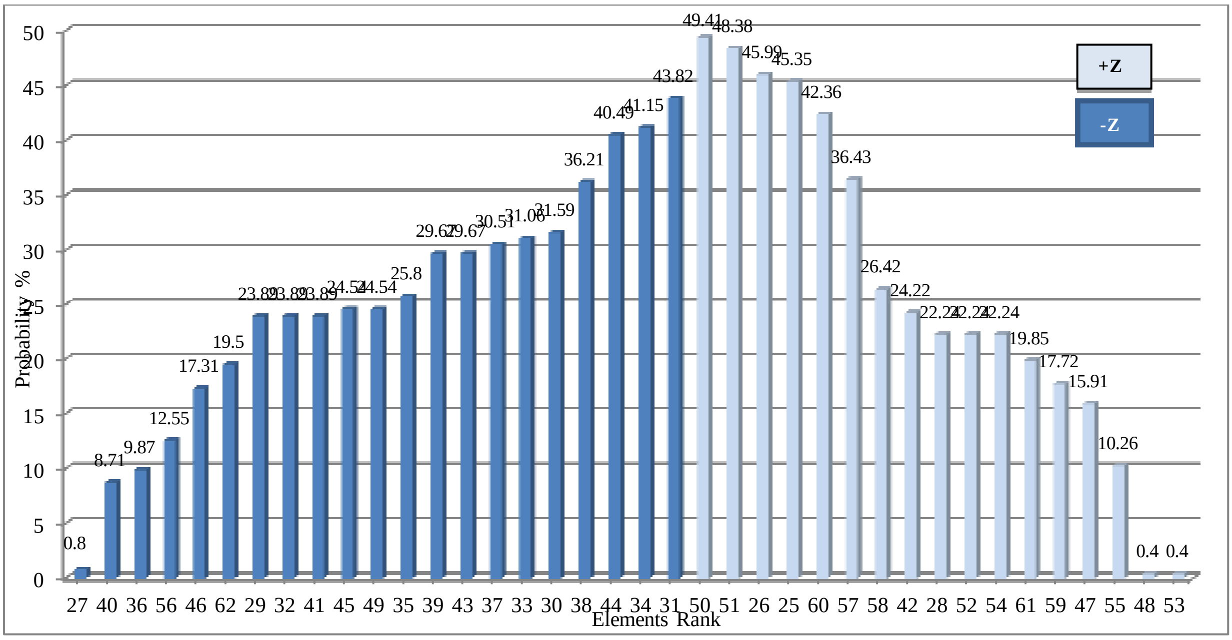


Fig14:The Probabilities and Elements Rank(Axis Three).

The results of the statistical analysis of water pollution control element (WPCE) were obtained for the three axis of water pollution control processes in Iraq.Figures (9),(10)&(11) show the values of responses weighted mean for (WPCE) according to elements rank and figures (12), (13) & (14) show the values of probability according to the elements rank. The probabilities indicate the relative importance of each element in water pollution control processes.

Table 2 diagnoses the reasons of faults in the water pollution control process in Iraq and suggests the corrective actions needed to improve the system.

Table2: Diagnosis of Faults and the corrective Actions for Water Pollution Control in Iraq.

Axis One		
Element No.	**Faults**	**Corrective Action**
2	-Formulation of International Policies.	-Actions Supporting the Development of An Enabling Environment.
5	-Water Resources Policy.	- Water Resources Statute.
4	-Regulations.	-Regulations and Local By Law.
8		
9		
10		
Axis Two		
Element No.	**Faults**	**Corrective Action**
23	-Management Structure.	-Actions Supporting Development of An Institutional Frame-work.
19	- Capacity Building.	- Management Structure.
18		- Capacity Building.
15		
24		
20		
Axis Three		
Element No.	**Faults**	**Corrective Action**
27	-Information System.	-Actions Enhancing Planning and Prioritization Capability.
40	-Assessment Tools.	-Enforcement.
36	-Management Procedures.	-Management Procedures.
56		-Application of Standard No 417.
46		-Application of Industrial, Recreational and Aquatic Life Criteria.
62		-Application of Domestic Water, Industrial Life and Criteria.
29		-Water Prizing Policy.
32		-Information System.
41		-Assessment of Impacts.
45		-Public Participation.
49		
35		

39		
43		
37		
33		
30		
38		
44		
34		
31		

Conclusions:

From the research context, find work and the development of "Water Quality Management System WQMS", the following could be concluded:

Water Quality Index System "WQIS"

1. The program can be used continuously by user to define water quality in terms of index numbers for the purpose of river water quality classification and potential water use.
2. The system is demonstrably sensitive to variations in quality and highlights river reaches which have shown a change in quality over a specified period. The system reflects water use, thus, providing information to operational managers for specific water uses. The computerized data handing enables the index to produce valuable management information in a timely and efficient manner.
3. The minimum sub-index value for each month and for each site indicates the significant effect of the determinant on defining the value of water quality index score.
4. Euphrates water &Shatt Al hilla water qualityare classified as class III & class IVfor general uses at all sites except; Shoumaly station&Thalya station at Shatt Al hillawhich represents class IV&class V for general uses.
5. Euphrates water &Shatt Al hilla water quality shows a better classification as irrigation water source than the other beneficial uses.
6. The water quality index classification can be used by the local environmental protection authorities as a management tool to monitoring the water quality of the river and upgrading its quality

Water Pollution Control System "WPCS"

1. The program can be used to diagnose the reasons of faults in the water pollution control processes in Iraq and highlights the corrective actions needed to improve the water pollution control processes.
2. The action plan in the water quality pollution control system "WPCS" provides a direction and a framework for achieving the goals concerning integrated water management in Iraq.
3. The approaches to be taken from "WPCS" are set out of strategic directions covering key sectors and policies, as prioritization and planning, enabling environment and institutional arrangements.
4. Reducing time by taking ready knowledge easily from the system and determining remedy for the Water Pollution Control problems which include arrival to an evaluation, advice, suggestion and decision making.
5. There is a lack in water pollution control experience in Iraq and there is a shortage in the water pollution control experienced staff. "WPCS" can help to overcome the lack of water pollution control experience and personnel of water resources management field.

References:

1. Alaa, A., O.,“Water Quuality Assessment in Middle- Euphrates Region in Iraq”, M.Sc. Thesis, College of Engineering, University of Babylon, 2010.
2. Horton, R.K. "An Index Number System for Rating Water Quality", J. Water Pollut. Control Fed. 37,3,PP.300-305, 1965.
3. Brown, R.M.; McClelland, N.I; Deininger R.A. And Tozer, R.G. "A Water Quality Index-DO we dare?", Water and Sewage works, 117, 10. PP. 339-343,1970.
4. McClelland, N.I.; Brown, R.M.; Dieningar, R.A. and Landwehr, J.M."Water Quality Index Application in the Kansas River Basin", EPA publication No. EPA-907/9-74-001, Feb,1974.
5. Scottish Development Department, "Development of a Water Quality Index",. Report ARD3. Applied Research and Development engineering Division, 1976.
6. Stojda, A. and Dojtido, J. "A study on the Water Quality Index in Poland", WHO Water Quality Bull. 8,I,PP.30-32, 1983.
7. Dojlido, J., Raniszewski, J. and Woysie Chowska, J., "Water Quality Applied to Rivers in the Vistula River Basin in Poland ", Environmental Monitoring and Assessment, vol.33, PP.33-42, 1994.
8. Bahargava, D.S. "Use of Water Quality Index for River classification and Zoning of Gang River", Envir. Pollut. Series, England,PP.62-67,1983.
9. Smith, D.G. "A Better Water Quality Indexing System for Rivers and Streams", J. Water Science and tech., 24,10,PP.1237-1244,1990.
10. ESCWA, "Development of Water Quality Indexed for Sustainable Development (A case-study)", Agent 21 for integrated Water Management in the ESCWA region, United Nation, New York, 1995.
11. Helmer, Richard and Hespanhol, Ivanildo**.** “ Water Pollution Control-A Guide to the Use of Water Quality Management Principles”, 1st edition, United Nations Environment Programme, Water Supply & Sanitation Collaborative Council and World Health Organization, London, http://www.earthprint.com, 11/2/2009.
12. Jerome, C.R., Li, "Statistical Inference", Edwards Brothers, Inc., Ann Arbor, Michigan, 1966.
13. Murry, R., Spiegel, "Theory and problems of statistics", schaums outline series in science, McGraw-Hill Book company,1972.
14. ESCWA, "Development of Water Quality Indexed for Sustainable Development(A case-study)", Agenda 21 for integrated Water Management in the ESCWA region, United Nation, New York,1995.
15. "Environmental Legislation" , Directorate of Improvement and Protection of Environment, 1998.
16. Pollution Reality and Environment Protection, Seminar held by Iraqi Chemists Union,June,2000.
17. T.H.Y TEBBUTT, "Principles of Water Quality Control", Butterworth-Heinemann, Linacre House, Jordan Hill, Oxford OX28 DP, 1998.

*****