Assessment of Water Quality of Tigris River by using Water Quality Index (CCME WQI)

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Abstract

The present work describes the application of Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) for the 3 stations located along with Tigris River in Baghdad city, Iraq. The field work was conducted during the period from February to December 2010. CCME WQI was applied using eleven water quality parameter (pH value, Total Dissolved Solids, Calcium, Total Alkalinity, Ammonia, Nitrate, Nitrite, Turbidity, Lead Chromium, Iron). Based on the results obtained from the index, the water quality of Tigris River ranged between 37-42 which indicate that river has the worst quality due to effect of various urban pollutant sources. This work confirms the need to take a serious action for monitoring the river for proper management.

Keyword: Assessment, Water Quality Index, CCME WQI, Tigris River, Baghdad-Iraq.

Introduction

Water is vital to the existence of all living organisms, but this valued resource is increasingly being threatened as human populations grow and demand more water of high quality for domestic purposes and economic activities. Water abstraction for domestic use, agricultural production, industrial production, power generation, mining, and forestry practices can lead to deterioration in water quality and quantity that impact not only the aquatic ecosystem (i.e., the assemblage of organisms living and interacting together within an aquatic environment), but also the availability of safe water for human consumption [28].

The quality of water required to maintain ecosystem health is largely a function of natural background conditions. Some aquatic ecosystems are able to resist large changes in water quality without any detectable effects on ecosystem composition and function, whereas other ecosystems are sensitive to small changes in the physical and chemical makeup of the body of water and this can lead to degradation of ecosystem services and loss of biological diversity. The degradation of physical and chemical water quality due to human influences is often gradual, and invisible adaptations of aquatic ecosystems to these changes may not always be readily detected until a dramatic shift in ecosystem condition occurs [13].

Typically, water quality is determined by comparing the physical and chemical characteristics of a water sample with water quality guidelines or standards. Drinking water quality guidelines and standards are designed to enable the provision of clean and safe water for human consumption, thereby protecting human health. These are usually based on scientifically assessed acceptable levels of toxicity to either humans or aquatic organisms [27- 18- 24].

One of the simplest methods to assess water quality conditions is by using water quality indices [31]. It is a tool that provides meaningful summaries of water quality data that are useful to both technical and non - technical individuals interested in water quality results. It is important to note that the CCME WQI is not a substitute for detailed analysis of water quality data and should not be used as a sole tool for management of water bodies. It was simply developed to provide a broad overview of environmental performance [19].

Any number of water quality measurements can serve, and have already been used, as indicators of water quality. However, there is no single measure that can describe overall water quality for any one body of water, let alone at a global level. As such, a composite index that quantifies the extent to which a number of water quality measures deviate from normal, expected or 'ideal' concentrations may be more appropriate for summarizing water quality conditions across a range of inland water types and over time. Although there is no globally accepted composite index of water quality, some countries and regions have used, or are using, aggregated water quality data in the development of water quality indices. Most water quality indices rely on normalizing, or standardizing, data parameter by parameter according to expected concentrations and some interpretation of 'good' versus 'bad' concentrations [30].

The Canadian Water Quality Index compares observations to a benchmark, where the benchmark may be a water quality standard or site specific background concentration [15-17-26]. The CWQI quantifies for one station, over a predate-rmined period of time (typically one year), the number of parameters that exceed a benchmark, the number of records in a dataset that exceed a benchmark, and the magnitude exceed of the benchmark. The index is flexible in terms of the bench- marks that are used for calculation, and depends on the information required from the index: that is, guidelines for the protection of aquatic life may be used (when available) if the index is being calculated to quantify ecological health of the water, or drinking water quality guide-lines may be used if the interest in the index is in drinking water safety. Alternatively, information describing natural back-ground conditions for a station or region may be used as benchmarks when trying to quantify deviation from natural conditions. Sites at which water quality measurements never or rarely exceed the benchmark have high CWQI scores (near 100), whereas sites that routinely have measurements that exceed benchmarks have low CWQI scores (near 0). The CCME WQI was developed with the intent of providing a tool for simplifying the reporting of water quality data [15]. It is a tool that provides meaningful summaries of water quality data that are useful to technical and policy individuals as well as the general public interested in water quality results. As a summary tool, it provides a broad overview of water quality data and is not intended to be a substitute for detailed analysis of water quality data. The application of the CCME WQI requires Water Quality Guidelines (WQGs) or Water Quality Objectives (WQOs). The model essentially consists of three measures of variance from selected WQGs or WQOs (scope, frequency, amplitude) that combine to produce a value between 0 and 100 that represents the overall water quality. The use of appropriate WQGs or WQOs in the CCME WQI is critical to the computation of representative and accurate water quality indices [23]. Indices simplify and reduce the required raw and primary date for describing water quality and its spatial variation can show the particular water quality problems within a river body, allowing for many managerial decisions to be made. In a simple definition about indices it can be said that indices are proper and simple tools to determine conditions of water quality and, like any other tool, this requires knowledge about principles and basic concepts of water and related issues [20]. Due to the lack of expert study and inspection of the water quality of most rivers of Iraq.

Material and Methods

Study Area The study area included 3 stations on Tigris River Within Baghdad city, the first was located at North of Baghdad in Sader Al-Qanat area, and the second at middle part in Al-Aoadia area, whereas the third station located at South part in Al-Zafrania area (Fig.(1)). The river divides the city into a two sides, the right (Karkh) and left (Risafa) section with a flow direction from north to south [9].

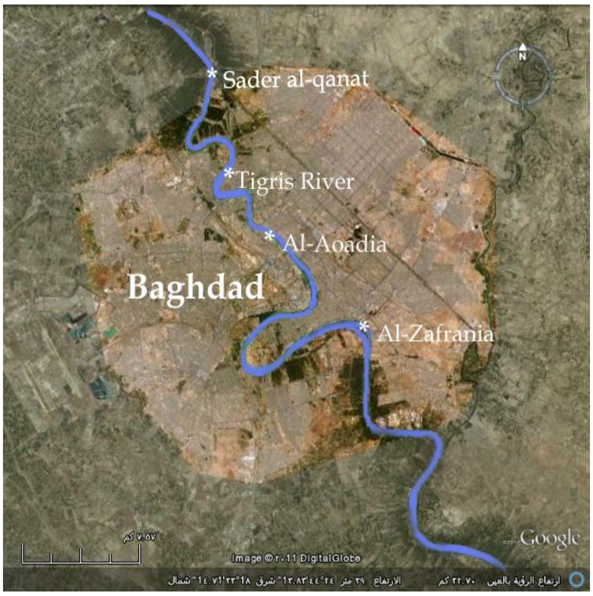

Fig.(1) Bagdad City Showing Sampling Station

The rainfall is seasonal varying from 40 to 100 mm annually, occurring mainly from November to April with 50% or more occurring between January and March. The temperature change between winter and summer is as great as between day and night. July and August are the hottest months with the temperature in the shade as high as 50° [4].

-Sampling

Subsurface water samples were collected from the middle and two banks of the Tigris river during February to December 2010 from each station by using clean polyethylene bottles. Samples were analyzed for chemical and physical properties immediately after collection.

The CWQI calculated by select a set of eleven parameters based on both importance and availability of data. these eleven parameter are pH value, Total Dissolved Solids, Calcium, Alkalinity, Ammonia, Nitrate, Nitrite, Turbidity, Chromium, Iron, Lead. CCME WQIs were computed for the three sites in the Tigris River using sets of standard values (table 2) [26-21-16]. The Iraq recommended Guidelines based objectives were applied to categorize the water primarily for use as drinking water.

-Calculation of the CCME WQI

The CCME WQI model consists of three measures of variance from selected water quality objectives (scope, frequency, amplitude). These three measures of variance combine to produce a value between 0 and 100 (with 1 being the poorest and 100 indicating the best water quality) that rep- resents the overall water quality. Within this range, designations have been set to classify water quality as poor, marginal, fair, good or excellent. These same designations were adopted for the indices developed here [22].

Table (1)
CCME WQI categorization schema [22].

Rank	*WQI Value*
Excellent	95-100
Good	80-94
Fair	65-79
Marginal	45-64
Poor	0-44

Table (2)
Standard Values .

Parameter	*Iraq*	*WHO*	*CCME*
pH (mg/l)	6.5-8.5	6.5-8.5	8.5
TDS (mg/l)	1000	500	500
Calcium (mg/l)	50	100	-
Total Alkalinity (mg/l)	-	100	-
Ammonia(mg/l)	-	0.2	1.37
Nitrate (mg/l)	50	50	48.2
Nitrite (mg/l)	3	3	-
Turbidity(NTU)	5	5	5
Chromium (mg/l)	0.05	0.05	0.05
Iron (mg/l)	0.3	0.3	0.3
Lead (mg/l)	0.01	0.01	0.01

The detailed formulation of the WQI, as described in the Canadian WQI 1.0–Technical Report [9], is as follows:

$$F_1 = \left[\frac{Number\ of\ Variables}{Total\ Number\ of\ Variables}\right] \times 100$$

The measure for scope is $F_1(Scope)$. This represents the extent of water quality guideline non-compliance over the time period of interest.

$$F_2 = \left[\frac{Number\ of\ Failed\ Tests}{Tolal\ Number\ of\ Tests}\right] \times 100$$

The measure for frequency is F_2 (*Freque-ncy*). This represents the percentage of individual tests that do not meet objectives (failed tests).

-Amplitude, F_3

The measure for amplitude is F_3. This represents the amount by which failed tests do not meet their objectives. This is calculated in three steps:

Step 1- Calculation of Excursion. Excursion is the number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective.

When the test value must not exceed the objective:

$$ecursion = \left[\frac{Failed\ Test\ Value\ i}{Objective}\right] - 1$$

When the test value must not fall below the objective:

$$excursion = \left[\frac{Objective}{Failed\ Test\ Value}\right] - 1$$

Step 2- Calculation of Normalized Sum of Excursions. The normalized sum of excu-rsions, *nse*, is the collective amount by which individual tests are out of compliance. This is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives).

$$nse = \frac{\sum_{i=1}^{n} excursion}{Number\ of\ Tests}$$

Step3- Calculation of F_3. F_3 ($Amplitude,$)is calculated by an asymptotic function that scales the normalized sum of the excursions from objectives to yield a range from 0 to 100.

$$F_3 = \left[\frac{nse}{0.01\ nse + 0.01}\right]$$

The WQI is then calculated as:

$$CWQI = 100 - \left[\frac{\sqrt{F_1{}^2 + F_2{}^2 + F_3{}^2}}{1.732}\right]$$

Result and Discussion

The indices have been primarily developed to reflect changes in the physicochemical quality of surface waters. However, they may be used as indicators of ecological change. Temporal variations occur within an aquatic system. by relating water quality to potential water use, the effect of this change on the system may be recorded [5].

Average values of CCME WQIs (range from 37 to 42) indicate that water quality for drinking uses can be rated as poor in all site (Fig.(2)). this may reflect the Discharge of pollutants to a water resource system from domestic sewers, storm water discharges, industrial wastes discharges, agricultural runoff and other sources, all of which may be untreated, can have significant effects of both short term and long term duration on the quality of a river system [3], and also the effect of dryness in the area in the last three years might be behind the clearly observed depletion of WQI [32].

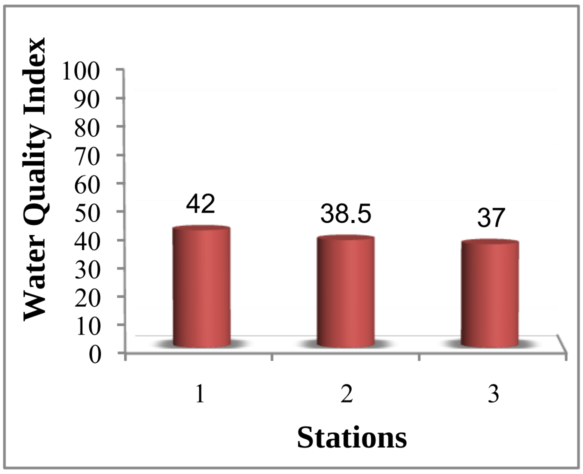

Fig.(2) Average of Water Quality Index.

The result of pH varied from (7.1- 8.4) in station 1 ,(7.3-8.2) in station 2 and (7.3-8.4) in station 3 indicating that the water sampler are almost neutral to sub-alkaline in nature. pH is an important factor that determines the suitability of water for various purposes[25].The recorded range of pH values in present study were general in accordance with the pH values of fresh waters [32] and agree with Iraqi published data [2-10] and were in permissible level recommended by the Iraq, WHO and CCME for drinking water.

The observed value of total Alkalinity was higher than the permissible level recommended by the WHO for drinking water. The statistical analysis showed a significant difference among all sites (P< 0.05) and significant fluctuate between months. The normal conduction of the alkalinity of natural waters are associated with carbon dioxide, bicarbonate, carbonate and hydroxide components. These factors are characteristic of the source of water and the natural processes taking place at any given time. For particular industrial and domestic use, it is often desirable to change these characteristic by treatments such as aeration, neutralization, softening, ect. [1].

Turbidity is widely concerned as an important parameter for drinking water. However, the observed value were higher than the permissible level recommended by the Iraq, WHO and CCME for drinking water for all months. The statistical analysis showed a significant difference among all sites (P<0.05).turbidity in water is caused by presence of suspended particles such as clay, silt, finely divided organic matter, plankton and other microscopic organisms [1].

Higher concentration of Ammonia observed in June at station 3 (1.31 mg/l). The observed value which was higher than the permissible level recommended by the WHO and for drinking water. and there was significant difference (P<0.05) among all sites and months. Nitrate was the abundant form of nitrogen compounds (33.225 mg/l), while Nitrite was found in small amount 0.0329 mg/l in February at station 1, Nitrite and Nitrate were in permissible level recommended by the Iraq, WHO and CCME for drinking water. The statistical analysis showed of Nitrate and Nitrite showed a significant difference among all sites (P<0.05). and significant difference between months. Ammonia produced when nitrogenous organic matter is destroyed by microbiological activity and is therefore found in many surface and groundwater's. Higher concentration occur in water polluted by sewage, fertilizers, agriculture wastes or industrial wastes containing organic nitrogen, free ammonia or ammonia salts[6]. Nitrogen compounds may enter water as nitrates or be converted to nitrates from agricultural fertilizers, industrial and packing house wastes, sewage, drainages. Nitrates in large amounts can cause "blue babies" (methemoglobinemia) in infants less than six months of age [1].

Dissolved Solids in natural water are usually composed of the sulfate, bicarbonate and chloride of calcium, magnesium and sodium [1]. The result showed that TDS value was in the permissible level recommended by the WHO and CCME for drinking water. but higher than permissible level recommended by the Iraq for drinking water, where values rang from (367 to 866). Primary sources for TDS in receiving waters are agricultural and residential runoff, leaching of soil contamination and point source water pollution discharge from industrial or sewage treatment plants [11].

The result of Calcium was higher than the permissible level recommended by the Iraq for drinking water. The statistical analysis showed a significant difference among all sites (P<0.05) and significant fluctuate among months (P<0.05). The Calcium enter a water supply by leaching from minerals within an aquifer. Common calcium-containing minerals are calcite and gypsum, also some human activities involved with increase calcium by increasing concentration of carbon dioxide which form the carbonic acid that eventually lead to dissolve the bituminous rocks [11].

The concentration of lead (Pb) exceeded the permissible level recommended by the Iraq, WHO and CCME for drinking water at most of the months, and the higher concentration of lead was recorded (0.3637 mg/l) at station 3 in December, The concentration of Iron (Fe) exceeded the permissible level recommended by the Iraq WHO and CCME for drinking water at most of the months and the higher concentration of lead was observed (0.77 mg/l) at staion3 in December. The concentration of Chromium (Cr) exceeded the permissible level recommended by the Iraq, WHO and CCME for drinking water at most of the months and the higher concentration of lead was recorded (0.43mg/l) in February. The statistical analysis of Heavy metal showed a significant difference between all site (P<0.05). Careless disposal of urban effluents, Runoff, atmospheric deposition and domestic and industrial effluent discharges are the major sources of aquatic pollution.[7-8-12-14-29]. from the result we obtained the parameter that sometime exceed the standard value was Turbidity, Alkalinity, Ammonia, Calcium, Dissolved Solids, Fe, Cr, except pb that was exceed the standard value all the time in all stations.

Conclusion

Using water quality indices for particular consumption is considered as a simple method for the primary recognition of river water quality. The use of index of water quality will not only allow assessment of changes in water quality over time and space but also evaluate successes and shortcomings of domestic policy and inter-national treaties designed to protect aquatic resources.

References

[1] Charles E. Reen (1970). "Investigating Water Problems: A Water Analysis Manual". Publishing by LaMotte Chemical Products Company, Chestertown, Maryland. 72pp.

[2] Maulood, B.K.; Hinton, G.C.F.; Kamees, H.S.; Saleh, F.A.K. ; Shaban, A.A.; Al-Shahwani, S.M.H. (1979). "An Ecological Survey of Some Aquatic Ecosystems in Southern Iraq" *Tropical Ecology*, 20(1): 27-40.

[3] Crabtree, R. W., Cluckie, I. D. & Forster, C. F. (1986) A comparison of two quality models. *Water Research*, 53-61.

[4] Al-Layla, M.A. & Al-Rizzo H.M. (1989). "A Water Quality Model for the Tigris River Downstream of Sadam Dam, Iraq". *Hydrologjeal Scie. J. Des Scie. Hydrolopques*, (34)6: 687-704.

[5] House, M. A.(1989). "A Water Quality Index for River Management". *Water and Environment J.*, 3(4)" 336-344.

[6] UNEP/WHO, United Nations Environment Programme and the World Health Organization(1996). "A practical Guide to the Design and Implementation Of Fresh Water Quality Studies and Monitoring Programme. Edi. by Jamie and Bartram and Richard Isbn 0419 22320 7(Hbk) 0 419 21730 4 (Pbk).

[7] Langmuir, D.(1997). "Aqueous Environmental Geochemistry". Prentice Hall, USA, 600pp.

[8] Wasswa, J. (1997). "Determination of levels of Pollutants within Sediments in Water Channels from Iindustries in Selected Parts of Lake Victoria". M.Sc., Thesis, Makerere University, Uganda, 119pp.

[9] Al-Adili, A.S. (1998). "Geotechnical Evaluation of Baghdad Soil Subsidence and their Treatment". Ph.D. Thesis, University of Baghdad, Iraq, 148pp. [in Arabic].

[10] Al-Saadi, H.A.; Kassim , T.I. ; Al- Lami , A.A.; Salman , S.K. (2000). "Spatial and Seasonal variations of phytoplankton populations in the upper region of the Euphrates River, Iraq". *Limnologica*, 30: 83-90 .

[11] Boyd, C.E. (2000). "Water Quality an Introduction". Kluwer Acadamic Publi-shers, Boston, USA, 330P.

[12] Linnik, P.M. & Zubenko, I.B. (2000). "Role of Bottom Sediments on The Secondary Pollution of Aquatic Environments By Heavy Metal Compounds". *Lakes and Reservoirs. Research & Management*, 5(1): 11-21 .

[13] Stark, J.R.; Hanson, P.E.; Goldstein, R.M.; Fallon, J.D.; Fong, A.L.; Lee, K.E.; Kroening, S.E.; & Andrews, W.J. (2000). "Water Quality in the Upper Mississippi River Basin, Minnesota, Wisconsin, South Dakota, Iowa, and North Dakota, 1995-98." United States Geological Survey, Circular 1211, Reston, Virginia, 36pp. available on-line at. *Http://Pubs.Usgs.Gov/Circ/Circ1211/Pdf/Circular1211.Pdf*.

[14] Campbell, 2001 Campbell, L.M. (2001). "Mercury in Lake Victoria (East Africa): Another Emerging Issue For A Beleaguered Lake" Ph. D, Thesis. Waterloo, Ontario, Canada, 145pp.

[15] CCME, Canadian Council of Ministers of the Environment (2001). "Canadian Water Quality Guidelines for the Protection of Aquatic Life: Canadian Water Quality Index 1.0 Technical Report". In Canadian Environmental Quality Guidelines, Winnipeg, Manitoba

(http://www.ccme.ca/assets/pdf/wqi_usermanualfctsht_e.pdf).

[16] Standard Specification (2001). Drink-ing Water, Iraq. First modernization, no.417, the Council Of Ministers, Central Apparatus For Assessment And Quality Control, 5pp. [in Arabic].

[17] Khan, F.; Husain, T. & Lumb, A.: (2003). "Water Quality Evaluation and Trend Analysis in Selected Watersheds of the Atlantic Region of Canada". *Environmental Monitoring and Assessment*, 88: 221–242.

[18] Dodds, W.K. & Oakes, R.M. (2004). "A Technique For Establishing Refe-rence Nutrient Concentrations Across Watersheds Affected by Humans". *Limnology and Oceanography Methods*, 2: 333-341.

[19] Khan, A.A.; Paterson R. & Khan, H. (2004). "Modification and Application of the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) for the Communication of Drinking Water Quality Data in Newfoundland and Labrador". *Water Quality Research Journal Canada*, 39: 285-293.

[20] Nikbakht, M. (2004). "The Effect Assessment of Ahvaz No.1,2 Water Treatment Plant on Karoon Water Quality". M.Sc. thesis, Ahvaz: IA University, 111pp.

[21] WHO, World Health organization (2004). "International Standards of Drinking Water". 3rd Edition, Volume 1, Recommendations, Geneva. 515pp.

[22] Haseen, K.; Amir, A.K.; Sarah, H. (2005). "the Canadian Water Quality Index: A Tool for Water Resource Management". Mterm International Conference, 06- 10 June, Ait, Thailand.

[23] Khan, A.A; Annette T.; Paterson, R.; Haseen K. & Richard W. (2005). "Application of CCME Procedures for Deriving Site Specific Water Quality Guidelines for The CCME Water Quality Index". *Water Quality Research Journal Canada*, 40(4): 448-456.

[24] Wickham, J.D.; Riitters, K.H.; Wade, T.G.; Jones, K.B. (2005). "Evaluating the Relative Roles of Ecological Regions and Land-Cover Composition for Guiding Establishment of Nutrient Criteria". *Landscape Ecology* 20(7): 791-798.

[25] Ahipathy, M.V. & Puttaiah, E.T. (2006). "Ecological Characteristics of Vrishabhavathy River in Bangalore (India) "*Environmental geology*, 49(8): 1217-1222.

[26] Lumb, A. ; Doug H. & Tribeni S. (2006). "Application of CCME Water Quality Index to Monitor Water Quality: A Case of The Mackenzie River Basin, Canada". *Environmental Monitoring and Assessment*., 113: 411-429.

[27] Robertson, D.M.; Saad, D.A.; & Heisey, D.M. (2006). "A regional Classification Scheme for Estimating Reference Water Quality in Streams Using Land Use Adjusted Spatial Re-gression-Tree Analysis". *Environmental Management*. 37 (2): 209-229.

[28] UNEP/GEMS, United Nations Environment Programme Global Environment Monitoring System/ Water Programme (2006). "Water Quality for Eco-system and Human Health". UN GEMS /Water Programme Office c/o National Water Research Institute 867 Lake-shore Road Burlington, Ontario, L7R 4A6 CANADA available on-Line. *http://www.gemswater.org/*.

[29] Lomniczi, I.; Boemo, A.; Musso, H. (2007). "Location and Characterization of Pollution Sites by Principal Component Analysis of Trace Contaminants in A Slightly Polluted Seasonal River: A Case Study of the Arenales River (Salta, Argentina)". *Water SA.*, 33(4): 479-485.

[30] UNEP/GEMS, United Nations Environment Programme Global Environment Monitoring System/Water Programme (2007). "Global Drinking Water Quality Index Development and Sensitivity Analysis Report". C/O National Water Research Institute 867 Lakeshore Road Burlington, Ontario, L7r 4a6 Canada. available on-line at. *http://www.Gemswater.Org*

[31] Salim, B.J.; Gholamreza, N.B.; Amir, S.; Masoud, T. & Mojtaba, A. (2009). "Water Quality Assessment of Gheshlagh River Using Water Quality Indices". *Environmental Science*, 6, (4):19-28.

[32] Al-Obaidy, A.H.M.J.; Bahram, K.M. & Abass, J.K. (2010). "Evaluating Raw and Treated Water Quality of Tigris River Within Baghdad by Index Analysis". *J. Water Resource and Protection*, 2: 629-635.

الخلاصة

يصف البحث الحالي تطبيق دليل نوعية المياه المعتمد على الموديل الكندي لثلاث محطات على نهر دجلة في مدينة بغداد. تم إجراء العمل الحقلي من شهر شباط 2010 الى شهر كانون الأول 2010. طبق دليل نوعية المياه المعتمد على الموديل الكندي باستخدام احد عشر عامل (الأس الهيدروجيني و المواد الصلبة الذائبة و الكالسيوم و القاعدية الكلية و الامونيا و النترات والنتريت والكدرة و الرصاص والكروم والحديد). اعتماداً على النتائج التي تم الحصول عليها من الدليل, فان نوعية مياه نهر دجلة تراوحت بين 37–42 والتي تشير الى تردي نوعية مياه النهر, نتيجة لتأثره بمختلف مصادر التلوث الحضرية. ان البحث الحالي يؤكد الحاجة الى اتخاذ إجراءات صارمة لمراقبة نهر دجلة لغرض الوصول الى برنامج أدارة مناسب.