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Research Article

Development of a multilateral Canadian Water Quality Index (C-WQI) for water supply applications

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Abstract: Securing freshwater quality for both ecological and human needs is thus an important aspect of integrated environmental management. A water quality index supplies a convenient means of epitomizing complex water quality data and easing its communication to a general public. Application of the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) as a communications tool for reporting the water quality results, where The CCMEWQI simplifies the communication of results while integrating local expert opinion. The CCME WQI index categorization schema was modified by removing a ranking element (Frequency). The Modify Index incorporates two elements: scope - the number of variables not meeting water quality objectives and amplitude - the amount by which the objectives are not met. The index results in a number between 100 (best water quality) and 0 (worst water quality). The modified index is validated by using data recorded from Al-Gharraf River in Iraq – 2017.The parameters selected for evaluation were: PH, Total Dissolved Solid (TDS), Alkalinity (AlK), Electrical Conductivity (EC), Calcium (Ca), Chloride (Cl), Sodium (Na), Sulfate (SO4), Potassium (k), Total suspended solids (TSS), Total hardness (TH). The modified index is compared with the original Canadian water quality index. In the period under study, the scores for both indexes resulted in a class good of quality, corresponding to an excellent water quality. The sensitivity analysis indicates a higher accuracy of the modified index model as compared to the Canadian index model. The modified index may be used as a communication tool for water quality towards the general public and do not combine multiple variables into a single value and thus increase the susceptibility of the indicator to the sensitivity of the ecosystems. Successfully tested the use of the CCME WQI on selected data sets, and developed a phased approach for its performance as a practical means of presenting available physical, organic and chemical.

Keywords: CCME-WQI, surface water, Modify index, water quality index.

INTRODUCTION

Population growth and Rapid industrialization have resulted in significant quantities of toxic, hard to degrade and persistent pollutants from industrial, agriculture and municipal activities. To represent water quality in a clear method different water quality indices are used which purpose at giving a single value to the water quality of a source, then reducing, simpler expression and enabling easy interpretation a huge amount of data (Tirkey *et al.*, 2013). The CCME Water Quality Index (1.0) depends on a formula developed by the British Columbia Ministry of Environment, Lands and Parks and modified by Alberta Environment, where the index combines three elements: scope, frequency, and amplitude (Rocchini and Swain, 1995). Tested the activity of the CCME WQI in capturing skilled assessments of drinking water quality, with a panel of drinking water quality experts. Hurley et al. 2012, recommend a modified index calculation procedure to accommodate parameters measured at different frequencies. The advantages are its capability to explain measurements of a variety of variables in a single number, but the loss of interactionsamong variables, the lack of portability of the index to different ecosystem types and the sensitivity of the results (Zandbergen and Hall, 1988). Select the CCME WQI as the most suitable depending on the possibility of modulating the objectives to be met by each variable for the specific end use as well as its flexibility in selecting parameters. Finally, stratify the CCME WQI to simulated dataset design three: risk to fish, episodes of discharge of urban wastewater, and eutrophication (Terrado *et al.*, 2010). Many ranges of water quality indexes have been

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developed to evaluate and classify water quality worldwide (Boyacioglu, 2007; Abbasi and Abassi, 2012). Dascalescu *et al.*, 2017 a proposed index is supported by using historical data (Prut River during the period February- December 2012) recorded by the online monitoring system, where the original Canadian water quality index is compared with the weighted index. For the period under study. The results showed the sensitivity analysis indicates a higher accuracy of the weighted index model. While Khan *et al.,* 2004 application of the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI), describes the development of the phased approach for calculating water quality indices, the rationale for modifying the existing CCME WQI index categorization schema and the testing methodology used. In addition, discusses the challenges encountered in using the CCME WQI. Also discussed the interests and downfalls of this application. The aim of this study is to develop a modified version of the CCME-WQI adapted to monitor in order to evaluate and classify the water, as a function of date and station specific (don't a loss of information by combining several dates to a single index value).

MATERIALS AND METHODS

Study Area

Al Kut Dam was established between (1934-1939) with the aim of feeding the Gharraf river, that branches before Al Kut dam (Directorate of Public Irrigation,1976),Where it is considered one of the Several dams were established along the Tigris River (Mosul dam, and Samarra Dam) for several purposes, water storage, flood protection, energy generation and agriculture . The river continues to flow, where it passes through AL Hay and Muwafaqiya district in Kut city, before entering the Nasiriya city. Nasiriya is located between latitude (30˚36′00″ _ 32˚00′00″ N) and longitude (45˚36′00″ _ 47˚12′00″ E) as shown Figure (1). Occupies Thi- Qar province, yet enters to interrupt (90 km) in the Kut city and the river continues flowing to the south. The river passes in the cities of Al-Fajr, Kalt Seker , Al-Rifai and Al-Nasr while for (168 km) distance from the beginning the river bifurcates into two rivers Shatt Al-Bdai, which ends into the Hammar marsh, and the second section is the Shatt Al-Shatra, which passes in Shatrah city and Gharraf city ends in the Hammar marsh also, a total length of (230) km from its start point to its outlet of the Nasiriya marshes.This location gave different climatic characteristics represented by the proportion of solar radiation higher, less moisture and rain (Higher Agricultural Council,1978). That was established four systems separate on the Gharraf river for the purpose of maintaining the high level of water at the start of the river (17.4 m) and Al bdai (10 m)(Abdul-Hassan *et al.*, 1989).

Proposed Model

Considering the index result calculation of the way proposed by the CCME, the original index (CCME, 2001) was proposed, according to Eq. (1):

$$\mathrm{CCME-WQI}_m = 100 - \frac{\sqrt{\mathrm{Fms}^2 + \mathrm{Fma}^2}}{1.414} \quad \ldots\ldots(1)$$

Where the factors: F_{ms} – scope, and F_{ma} – amplitude, the original and the mentioned factors are specified with the formulas presented in Table (1).

The factor F_{ms} (scope) is calculated as the ratio between the number of the failed variables that do not meet the quality objectives to the total number of variables.

The factor F_{ma} (amplitude) considers the importance factor for each of the variables in the computation of the normalized sum of excursions(nse). In this manner, the excursion represents failed variable value to an objective. In the case of a parameter perchance with a significant water quality impact will have a larger assistance to the decrease of the index value.

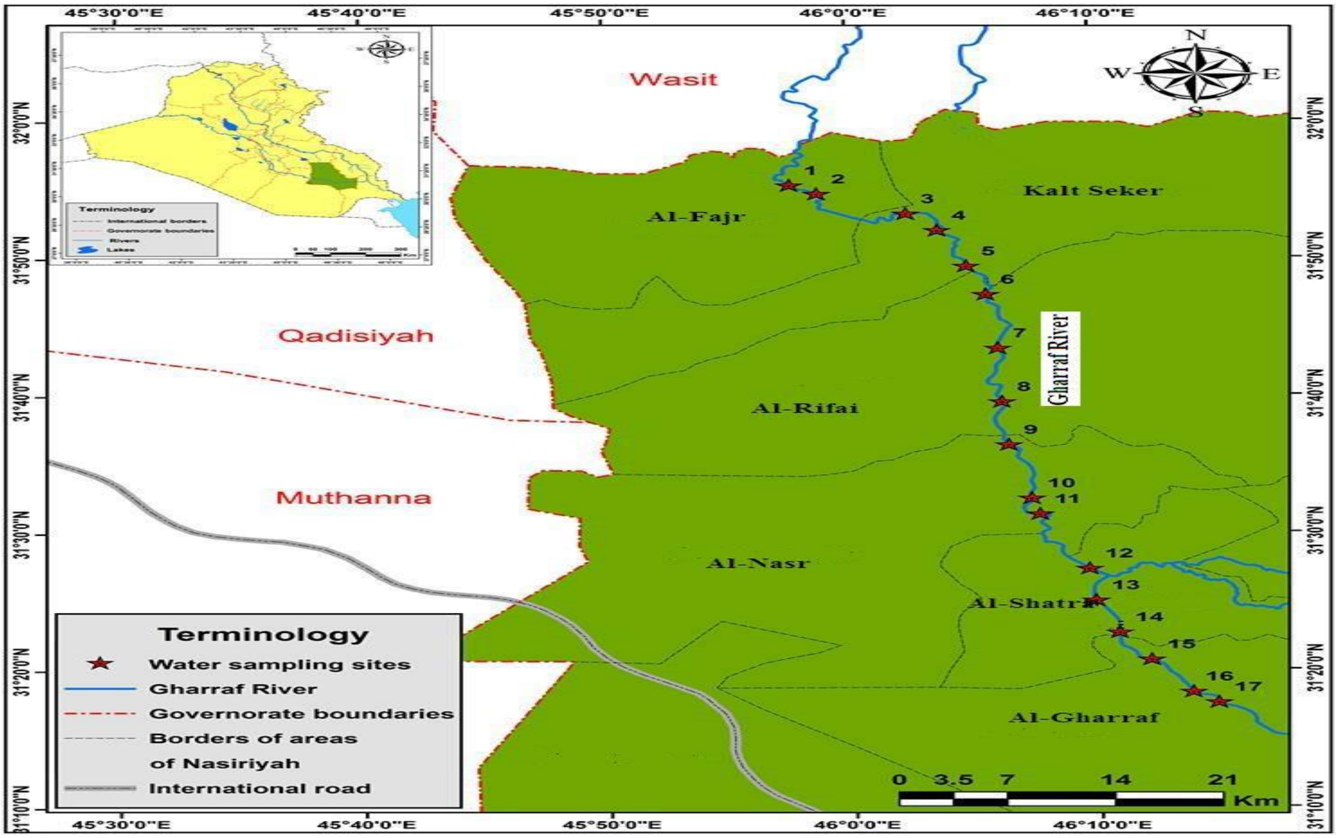

Figure 1: Location of the study area (Al- Gharraf River)

Table 1. Formulas for the calculation of the modify quality index compared with *CCME-WQI* (CCME, 2001)

Original CCME-WQI formula	***Modify formula (this study)***
$F1 = \frac{number\ of\ failed\ varibles}{total\ number\ of\ varibles} * 100$	$F_{ms} = \frac{number\ of\ failed\ varibles}{N\_constant} * 100$
$F2 = \frac{number\ of\ failed\ tests}{total\ number\ of\ tests} * 100$	There is no need to calculate the frequency value because we are dealing with the prevention of the collection of interactions between variables for a number of months (to obtain a more accurate result and credibility and the lack of confusion between the data thus the loss of evidence and interactions between them)
$\text{excursion} = \frac{failed\ test\ value}{objective} - 1$ $nse = \frac{\sum \text{excursion}}{number\ of\ test}$ $F3 = \frac{nse}{0.01nse + 0.01}$	$\text{excursion} = \frac{failed\ varible\ value}{objective} - 1$ $nse = \frac{\sum \text{excursion}}{N\_constant}$ $F_{ma} = \frac{nse}{0.01nse + 0.01}$

where: N _constant– total number of variables; nse _ normalized sum of excursions; $F_{ms_}$modify scope; $F_{ma_}$modify amplitude.

Collection Data

The modified model for the calculation of the water quality index was applied by using the data recorded from Al-Gharraf River in Iraq. The water quality physical and chemical parameters, which are 11 parameters including: PH, Total Dissolved Solid (TDS), Alkalinity (AlK), Electrical Conductivity (EC), Calcium (Ca), Chloride (Cl), Sodium (Na), Sulfate (SO_4), Potassium (k), Total suspended solids (TSS). The water samples collected from the study station were for two seasons 4/FEB and 11/MAY, as shown Table (2). These samples(17 station) were taken from depth 20 cm the surface of the water and keep in plastic bottles for examination in the laboratory, but the parameters (T.D.S, E.C and PH) were examined in situ by (ph-meter &oakton pcs testr 35) devices.

Table 2. Summary of variables measured from Al-Gharraf River in Iraq-2017

	Date	**pH**	**Ec** µs/cm	**Alk mg/l**	**TH mg/l**	**Ca mg/l**	**Cl mg/l**	**So_4 mg/l**	**Na mg/l**	**K mg/l**	**TDS mg/l**	TSS **mg/l**
1	4-Feb-2017	7.85	1494	128	**486**	121	153	**413**	142.8	4	1016	60
	11-May-17	8.4	828	74	294	73	90	181	74.7	2.4	564	34
2	4-Feb-2017	8.01	1568	136	**508**	127	148	**281**	146	4.4	1022	44
	11-May-17	8.40	790	72	290	72	88	186	73.5	2.1	446	58
3	4-Feb-2017	8.18	1471	128	**482**	120	146	**405**	143.2	4	1018	30
	11-May-17	8.3	808	72	294	73	89	171	75.6	1.8	482	34
4	4-Feb-2017	8.24	1477	128	**482**	120	148	**408**	142.4	4	1020	58
	11-May-17	8.3	808	72	294	73	89	181	74.7	2.4	598	24
5	4-Feb-2017	8.25	1476	128	**482**	120	140	**386**	145.2	4	1026	60
	11-May-17	8.3	818	74	292	73	88	171	75.6	2.4	560	48
6	4-Feb-2017	8.3	1474	128	**482**	120	143	**395**	146.5	4	1030	36
	11-May-17	8.4	816	74	294	73	88	176	76.2	2.4	486	56
7	4-Feb-2017	8.31	1472	126	**482**	120	144	**392**	144.8	4	1032	**70**
	11-May-17	8.5	836	76	**304**	76	89	**217**	77.7	2.4	598	52
8	4-Feb-2017	8.39	1467	126	**482**	120	146	**497**	145.2	4	1036	42
	11-May-17	8.4	816	74	294	73	89	**202**	77.4	2.4	562	60
9	4-Feb-2017	8.43	1497	128	**486**	121	144	**397**	142	4	1026	22
	11-May-17	8.4	816	74	294	73	89	**204**	76.8	2.4	556	38
10	4-Feb-2017	8.4	1480	128	**486**	121	140	**374**	145.2	4	1030	56
	11-May-17	8.4	827	76	294	73	90	182	76.5	2.1	494	42
11	4-Feb-2017	8.42	1480	128	**486**	121	143	**404**	143.2	4	1028	**72**
	11-May-17	8.3	851	76	**304**	76	94	208	78	2.1	488	68
12	4-Feb-2017	8.42	1478	128	**482**	120	144	**408**	144.4	4	1024	**66**
	11-May-17	8.6	848	76	**304**	76	92	**246**	79.5	2.4	680	38
13	4-Feb-2017	8.43	1481	128	**482**	120	153	**408**	145.2	4	1022	28
	11-May-17	8.4	846	76	**304**	76	93	**205**	75.9	2.4	450	36
14	4-Feb-2017	8.58	1485	128	**482**	120	149	**413**	144.8	4	1018	36
	11-May-17	8.4	855	76	**304**	76	94	**214**	76.5	2.4	646	40
15	4-Feb-2017	**8.8**	1484	128	**482**	120	144	**394**	145.6	4	1022	28
	11-May-17	8.6	881	78	**308**	77	98	**208**	89.7	3.9	602	36
16	4-Feb-2017	8.6	1502	130	**486**	121	149	398	145.2	4	1036	40
	11-May-17	8.5	866	78	**308**	77	100	**214**	79.2	2.4	526	54
17	4-Feb-2017	8.3	1532	132	**490**	122	137	402	146.8	4.4	1040	56
	11-May-17	8.5	872	78	**308**	77	102	**220**	76.5	2.4	628	16
OBJECTIVE		*4-8.6*	2250	*200*	*300*	450	250	200	*250*	100	2500	60

Bolded values do not meet the objective

Water quality classification

After the working on the index computed model, scores between (0-100) lowest and excellent quality respectively. Classify the water quality, six classes of quality were set, with a corresponding standard (Table 3). Water quality classification considered the data available in the literature (Durmishi *et al.*, 2012).

Table 3. Classification of quality modify index.

Class	***Range***	***Description***
Excellent	95-100	No necessary treatment
Very good water quality	94 – 90	Requires a standard physical treatment
Good water quality	89 – 80	Requires a conventional physical and chemical treatment process:
Medium water quality	79 – 65	Requires an advanced treatment
Poor water	65 – 45	Polluted water
Very poor water	44 - 0	Not usable for drinking purposes

RESULTS AND DISCUSSION

The water quality index was determined by using the data recorded from Al-Gharraf River in Iraq during 2017according to Table (2). Both original CCME-WQI model and modify CCME-WQI model proposed in this study was applied. The variation of CCME-WQI model compared to modifying CCME-WQI model variation as a function of relative variation of measured quality parameters is presented in the solution below for station 10.

$$\boldsymbol{F1 = \frac{2}{11} * 100 = 18.18}$$

$$\boldsymbol{F2 = \frac{2}{22} * 100 = 9.09}$$

$$\boldsymbol{excusion = \frac{486}{300} - 1 = 0.62\ , etc.}$$

$$\boldsymbol{nse = \frac{0.62 + 0.87}{22} = 0.067}$$

$$\boldsymbol{F3 = \frac{0.067}{0.01 * 0.067 + 0.01} = 6.279}$$

$$\boldsymbol{CCME - WQI = 100 - \frac{\sqrt{20^2 + 2.9^2 + 2.8^2}}{1.732} = 87.71}$$

Given the category ranges suggested original index (CCME, 2001), the water quality at this river reach would be rated as “Good” based on for two seasons 4/FEB and 11/MAY 2017 data, but according to the modified index for example, we choose (11-May-17) data for station 10.

$$F_{ms} = \frac{0}{11} * 100 = 0$$

$$\text{excursion} = 0$$

$$\boldsymbol{nse = 0}$$

$$F_{ma} = \frac{0}{0.01 * 0 + 0.01} = 0$$

$$\text{CCME} - \text{WQI}_m = 100 - \frac{\sqrt{0^2 + 0^2}}{1.414} = 100$$

Given the category ranges suggested modify index, the water quality at this river reach would be rated as “Excellent”.

As observed from above, the negative trend for the original index (CCME-WQI) is associated with a decrease of water quality, as a result of its ability to represent measurements of a variety of variables in a single number. Then, loss of information by combining several variables with a different date to a single index value and the loss of interactions among variables. Therefore, the lack of portability of the index to different ecosystem types and the sensitivity of the results.

Table below show the WQI output and (F_{ms}, F_{ma} values) 4-Feb-2017 and (F_{ms}, F_{ma} values) 11-May-2017 for each station of parameters for the data used in this study.

Station	Modify CCME-WQI 4-Feb-2017			Modify CCME-WQI 11-May-2017		
	F_{ms}	F_{ma}	WQI	F_{ms}	F_{ma}	WQI
1	18.18	13.04	84.17	0	0	100
2	18.18	8.26	85.87	0	0	100
3	18.18	12.28	84.48	0	0	100
4	18.18	13.04	84.17	0	0	100
5	18.18	12.28	84.48	0	0	100
6	18.18	12.28	84.48	0	0	100
7	27.27	13.04	78.62	18.18	0.79	87.13
8	18.18	15.96	82.89	9.09	0.89	93.54
9	18.18	12.28	84.48	9.09	0.09	93.57
10	18.18	11.50	84.78	0	0	100
11	27.27	13.79	78.38	27.27	1.57	80.68
12	27.27	13.79	78.38	18.18	2.15	87.05
13	18.18	13.04	84.17	18.18	0.29	87.14
14	18.18	13.04	84.17	18.18	0.69	87.13
15	27.27	12.28	78.84	18.18	0.59	87.13
16	18.18	13.04	84.17	18.18	0.79	87.13
17	18.18	13.04	84.17	18.18	1.08	87.12

CONCLUSIONS

- The detection of episodes of point-pollution is possible, which otherwise would remain unrevealed when working to combine data, although they could have a significant impact on the quality of the water body. A modified version of CCME-WQI was proposed, considering the needs to fit it to the particularities of physical and chemical properties, which effectively characterize the water quality of the sources used for multilateral purposes when the required treatment level is evaluated.

- 2-The complex data are translated in a clear diagnosis, by defining six classes of water quality for a different range of scores, between 0 and 100.

- The a modified version of CCME-WQI was proposed, considering the needs to fit it to the particularities of physical and chemical properties, which effectively characterize the water quality of the sources used for multilateral purposes when the required treatment level is evaluated.

- 4-the modified index provides a negative modification as compared to the original a positive modification, when do not combine multiple variables into a single value and thus increase the susceptibility of the indicator to the sensitivity of the ecosystems, ensuring a higher accuracy of the water quality assessment.

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