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Total Water Quality Index Using Weighting Factors and Standardized into a Parameter

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Abstract

The aim of this paper is to present a new approach to assessing water quality by using a new index: "Total Water Quality Index" ("TWQI"). TWQI Method has advantages over other methods in evaluating water quality and has been applied in Belgium, the United States of America ("WQI") and Canada ("CWQI"). In the TWQI Method, the weighting factors ("Wi") were calculated, taking into account the toxic levels of each parameter and the hierarchical tables of water quality depended on the sum of number of parameters surveyed ($2 \leq n \leq 100$) were all calculated by theoretical formulae, and not predefined as in other methods. The results of using TWQI in assessing coastal waters (13 parameters) are consistent with the actual data monitored.

Keywords: weighting factors; standardize; total water quality index

1. Introduction

Currently, most countries are adopting the three main methods for comprehensive assessment of water environment quality as follows:

The Water Quality Index Method ("WQI") as used in the United States of America ("US") (Wayne, 1978), despite it used weighting factors W_i, but these W_i were scored by experts and hence this method still regarded subjective. The hierarchical ratings scale, which assessed five levels (very poor, poor, moderate, good and excellent), is predetermined and number of parameters being monitored is still limited (9 parameters). Rating scale limits are fixed are not dependent on the total number (n) of parameters examined and may result in the assessment thresholds do not match reality. Especially, calculation of the index requires building too complex correlated schemata, not convenient for applying into reality. For example, when the total number (n) of the parameters equals 30 ($n=30$), there will be a requirement to build 30 index schemata I_i.

In Belgium a scoring system, numbered 1 to 4, is used for assessing water quality and whilst the number (n) of surveyed parameters remain limited to four ($n=4$), weighting factors W_i are not used in the calculations.

In Canada, the method of water quality assessment CWQI (CCME, 2001) had an advantage in that it uses an unlimited number of parameters, but did not mention to weighting factor (W_i) in consideration of each surveyed parameter's importance. Rating scales are fixed and assessments tend therefore to be subjective. Most importantly, assessment thresholds do not reflect reality when $n=2$ or the number n of surveyed parameters are big.

In Vietnam, the General Department of Environment issued a new method for calculating the water quality index in 2010 (Vietnam Environment Administration, 2010). However, this method also has similar limitations to those referred to earlier.

2. Building the Total Water Quality Index ("TWQI").

2.1. Setting formula for Total Index P_j

This method allows consideration of the case at a monitoring point, corresponding to time t, with n of parameters acting at the same time. From this, it follows:

$$P_j' = \sum_{i=1}^{n} q_{ji} = \sum_{i=1}^{n} \frac{C_{ji}}{C_{ji}^*} \quad (1)$$

Where j=1, 2, 3,..., N and represents the number of Monitoring Points; n is the number of Parameters subject to monitoring; $q_{ji} = \frac{C_{ji}}{C_{ji}^*}$ - the Environment Quality Index of parameters (i) at Monitoring Point (j); C_{ji} is the average value of parameter (i) from the total number of samples observed automatically or sampling for analysis at Monitoring Point (j); C^*_{ji} is permitted limit value of parameter (i) at point (j) in accord with national standard of each country; P'_j is the Total Index at Monitoring Point (j).

From (1) we have: $P'_j = q_{j1}\left(\frac{q_{j1}}{q_{j1}} + \frac{q_{j2}}{q_{j1}} + \dots + \frac{q_{jn}}{q_{j1}}\right)$ (2)

Insert $q_{ji} = \frac{C_{ji}}{C^*_{ji}}$ and $q_{j1} = \frac{C_{j1}}{C^*_{j1}}$ into (2) it follows:

$$P'_j = q_{j1}\left(\sum_{i=1}^{n} \frac{C_{ji}}{C^*_{ji}} \times \frac{C^*_{j1}}{C_{j1}}\right) = q_{j1}\sum_{i=1}^{n} W'_i \frac{C_{ji}}{C_{j1}} \quad (3)$$

with $$W'_i = \frac{C^*_{j1}}{C^*_{ji}} \quad (4)$$

W'_i take into account the importance of parameter (i) in compare with the parameter selected as a standard in correspond with i=1 at point (j).
To calculate the importance of a single parameter (i) against n parameters, multiply the two sides of equation (3) with: $\frac{1}{\sum_{i=1}^{n} W'_i}$. This results in:

$$P_j = \frac{1}{\sum_{i=1}^{n} W'_i} P'_j = q_{j1}\sum_{i=1}^{n} \frac{W'_i}{\sum_{i=1}^{n} W'_i} \times \frac{C_{ji}}{C_{j1}} = q_{j1} \times \sum_{i=1}^{n} W_i \frac{C_{ji}}{C_{j1}} \quad (5)$$

Since the values for q_{j1} differ from those of q_{11}, so to convert P_j into the same Standard Index represented by q_{11} or C_{11}, we reformulate (5) above as follows:

$$P_j = q_{11}\left(\frac{q_{j1}}{q_{11}}\sum_{i=1}^{n} W_i \frac{C_{ji}}{C_{j1}}\right) = q_{11}\left(\frac{C_{j1}}{C_{11}}\sum_{i=1}^{n} W_i \frac{C_{ji}}{C_{j1}}\right) = \frac{C_{11}}{C^*_{11}} \alpha_j \quad (6)$$

with $$\alpha_j = \frac{C_{j1}}{C_{11}} \times \sum_{i=1}^{n} W_i \frac{C_{ji}}{C_{j1}} \quad (7)$$

of which $C^*_{11} = C^*_{j1}$ - Permited limit values of the parameter selected as a standard in accordance with the i=1, its value is the same at all Monitoring Points (j); α_j is the total coefficient of the standardized parameter; P_j - Total Index of the standardized parameter;

$$W_i = \frac{W'_i}{\sum_{i=1}^{n} W'_i} \quad (8)$$

is the weighting factor of parameter (i);
C_{ji} - Average value of parameters (i) from the total number of parameters analyzed in the process of monitoring at Monitoring Point (j); C_{j1} - Average value of the Standardized Parameters at Monitoring Point (j).

2.2. Establishing formula for TWQI and for water quality assessment scale

2.2.1. Establishing formula for TWQI

Dividing the set of n of numbers of q_{ji} from (6) into two groups:
Group 1 includes m of numbers of qji with values ≤ 1 (in accordance with the permitted standards set by the governments of individual countries):

$$P_{jm} = \sum_{i=1}^{m} q_{ji} = q_{11} \times \alpha_{jm},\ \alpha_{jm} = \frac{C_{j1}}{C_{11}} \times \sum_{i=1}^{m} W_i \frac{C_{ji}}{C_{j1}} \quad (9)$$

Group 2 included k of numbers of qji with values > 1 (not consistent with the permitted standards set by the governments of individual countries):

$$P_{jk} = \sum_{i=1}^{k} q_{ji} = q_{11} \times \alpha_{jk}\ ,\ \alpha_{jk} = \frac{C_{j1}}{C_{11}} \times \sum_{i=1}^{k} W_i \frac{C_{ji}}{C_{j1}} \quad (10),$$

where n = m + k. Standardize P_{jm} and P_{jk} into a Rating Scale of 100, and because $P_{jm} + P_{jk} = P_j$, we have:

$$\frac{P_{jm}}{P_j} \times 100 \text{ and } \frac{P_{jk}}{P_j} \times 100.$$

Currently, there are two approaches to creating a rating scale. Firstly, by assessment relative to a Pollution Index ("EPI") (an index increase, indicates a level of pollution increase which in turn affects the environment adversely) and secondly, by reference to the Environment Quality Index ("EQI") (a decrease in the EQI signifies a worsening affect on the environment).

For comparison with foreign models (CWQI and WQI) the second approach is used. To be uniform in the Rating Scale 100, it is necessary to establish the formula for TWQI at any Monitoring Point (j) as follows:

$$\begin{aligned} TWQI &= 100 - \frac{P_{jk}}{P_j} \times 100 = 100 \times \left(1 - \frac{P_{jk}}{P_j}\right) \\ &= 100 \times \left(1 - \frac{q_{11} \times \alpha_{jk}}{q_{11} \times \alpha_j}\right) = 100 \times \left(1 - \frac{\alpha_{jk}}{\alpha_j}\right) \\ &= 100 \times \left(1 - \frac{\frac{C_{j1}}{C_{11}}\sum_{i=1}^{k} W_i \frac{C_{ji}}{C_{j1}}}{\frac{C_{j1}}{C_{11}}\sum_{i=1}^{n} W_i \frac{C_{ji}}{C_{j1}}}\right) \quad (11) \\ &= 100 \times \left(1 - \frac{\sum_{i=1}^{k} W_i \frac{C_{ji}}{C_{j1}}}{\sum_{i=1}^{n} W_i \frac{C_{ji}}{C_{j1}}}\right) \end{aligned}$$

2.2.2. Setting Assessment Thresholds of TWQI

- Assessment thresholds must be set in the way so that the index TWQI fall into one of the domain hierarchy

- Assessment thresholds must satisfy the rating scale 100, corresponding with the TWQI Rating Scale

The assessment thresholds must, therefore, depend on the ratio $\frac{k}{n}\times 100$ in which k represents the number of parameters whose values are not in accordance with the permitted standards set by the government of individual countries, and n represents the total number of parameters monitored:

$$A_k = 100-\frac{k}{n}\times 100 = 100\times(1-\frac{k}{n}) \quad (12)$$

Since n must be a positive interger ($2\leq n\leq 100$), and k= 0, 1, 2,... it follows:

1) Environmental Quality is:

Excellent: Upper limit on the Rating Scale=100, when k=0.

Worst: Lower limit on the Rating Scale=0, when k=n.

2) A Good assessment threshold is attained when the minimum k=1, or $A_k = 100\times(1-\frac{1}{n}) = 100\times\frac{n-1}{n}$

3) A poor assessment threshold:

When n is represented by an even number: $k=\frac{n}{2}$, or

$$A_k = 100\times(1-\frac{n}{2n}) = 50$$

When n is represented by an odd number: $k=\frac{n+1}{2}$, or

$$A_k = 100\times(1-\frac{n+1}{2n}) = 50\times\frac{n-1}{n}$$

4) An Moderate assessment threshold is the average of two assessment thresholds of good and poor:

With n represented by an even number, it follows that:

$$A_k = (100\times\frac{n-1}{n}+50):2$$

$$= 25\times(2\times\frac{n-1}{n}+1) = 25\times\frac{3n-2}{n}$$

With n represented by an odd number, it follows that:

$$A_k = (100\times\frac{n-1}{n}+50\times\frac{n-1}{n}):2 = 75\times\frac{n-1}{n}$$

5) A very poor assessment threshold is attained when the maximum k = n-1 , or $A_k = 100\times(1-\frac{n-1}{n}) = \frac{100}{n}$

Based on a Basic assessment thresholds there follows Rating Scale as detailed below in Table 1.

2.2.3. The Method for calculating weighting factor W_i and product $W_i\frac{C_{ji}}{C_{j1}}$ in the sum in formula (11)

1) For general sum $\sum_{i=1}^{n} W_i\frac{C_{ji}}{C_{j1}}$ at any Monitoring Point (j)

+ To calculate the W_i, it is necessary, first of all, to calculate the product $W_i'\frac{C_{ji}}{C_{j1}}$. It is necessary to consider the following cases:

Case 1: When the lower standard $C_{ji}\leq C_{ji}^*$ (for example, to TSS, NH_4^+, As, etc.), then $q_{ji} = \frac{C_{ji}}{C_{ji}^*}\leq 1$

Table 1. Hierarchical table of water quality with even (n) and odd (n) at any Monitoring Point (j)

	TWQI even (n)			TWQI odd (n)		Water quality	Colour
$100\times\frac{n-1}{n}$	<TWQI≤	100	$100\times\frac{n-1}{n}$	<TWQI≤	100	Excellent	Blue
$25\times\frac{3n-2}{n}$	<TWQI≤	$100\times\frac{n-1}{n}$	$75\times\frac{n-1}{n}$	<TWQI≤	$100\times\frac{n-1}{n}$	Good	Green
50	<TWQI≤	$25\times\frac{3n-2}{n}$	$50\times\frac{n-1}{n}$	<TWQI≤	$75\times\frac{n-1}{n}$	Moderate	Yellow
$\frac{100}{n}$	<TWQI≤	50	$\frac{100}{n}$	<TWQI≤	$50\times\frac{n-1}{n}$	Poor	Orange
0	<TWQI≤	$\frac{100}{n}$	0	<TWQI≤	$\frac{100}{n}$	Very Poor	Red

Note: Considering the particular cases

From table 1, we found:

When n=2, the assessment thresholds “Very Poor”, “Poor”, “Moderate” and “Good” coincide with each other; when n=3, the assessment threshold “Very Poor” coincides with assessment threshold “Poor”. This is illustrated in Table 2.

Table 2. Hierarchical table of water quality when n=2 and n=3 at any Monitoring Point (j)

TWQI n = 2	Water quality	TWQI n = 3	Water quality
$50 < TWQI \leq 100$	Excellent	$70 < TWQI \leq 100$	Excellent
$0 \leq TWQI \leq 50$	Poor	$50 < TWQI \leq 70$	Good
		$33 < TWQI \leq 50$	Moderate
		$0 \leq TWQI \leq 33$	Poor

(is consistent with the permitted standards for individual countries) and $q_{ji} = \frac{C_{ji}}{C^*_{ji}} > 1$ (is not consistent with the permitted standards for individual countries), if $C_{ji} > C^*_{ji}$

Because $q_{ji} = \frac{C_{ji}}{C^*_{ji}}$, $q_{j1} = \frac{C_{j1}}{C^*_{j1}} = \frac{C_{j1}}{C^*_{11}}$, so

$\frac{q_{ji}}{q_{j1}} = \frac{C_{ji}}{C^*_{ji}} \times \frac{C^*_{11}}{C_{j1}} = \frac{C^*_{11}}{C^*_{ji}} \times \frac{C_{ji}}{C_{j1}} = W'_i \times \frac{C_{ji}}{C_{j1}}$ where

$$W'_i = \frac{C^*_{11}}{C^*_{ji}} \quad (13)$$

Case 2: With reference to the upper standard $C_{ji} \geq C^*_{ji}$ (for example with DO)

If $C_{ji} \geq C^*_{ji}$ (being consistent with permitted standards for individual countries), it follows that $\frac{C^*_{ji}}{C_{ji}} \leq 1$.

If, on the contary, $C_{ji} < C^*_{ji}$ then the opposite will apply $C_{ji} < C^*_{ji}$ (not consistent with permitted standards for individual countries).

Then, by using the way of calculation $\frac{q_{ji}}{q_{j1}}$ in case 1, it follows $\frac{C^*_{ji}}{C_{ji}} \times \frac{C^*_{11}}{C_{j1}} = W'_i \times \frac{1}{C_{ji}C_{j1}}$, with a weighting factor $W'_i = C^*_{ji} \times C^*_{11}$ (14)

Case 3: The permitted standards in a segment [a, b] (for example pH), where a, b are the upper and lower limits of permitted standards for parameter (i):

- If C_{ji}<a, then $\frac{a}{C_{ji}} \times \frac{C^*_{11}}{C_{j1}} = W'_i \times \frac{1}{C_{ji} \times C_{j1}}$, with

$$W'_i = a \times C^*_{11} \quad (15)$$

- If C_{ji}> b, then $\frac{C_{ji}}{b} \times \frac{C^*_{11}}{C_{j1}} = \frac{C^*_{11}}{b} \times \frac{C_{ji}}{C_{j1}} = W'_i \times \frac{C_{ji}}{C_{j1}}$

with $W'_i = \frac{C^*_{11}}{b}$ (16)

-If C_{ji}€[a,b], then $\frac{C_{ji}}{C_{ji}} \times \frac{C^*_{11}}{C_{j1}} = 1 \times \frac{C^*_{11}}{C_{j1}} = C^*_{11} \times \frac{1}{C_{j1}}$

$= W'_i \times \frac{1}{C_{j1}}$ with $W'_i = C^*_{11}$ (17)

+ In addition the product is calculated as being $W_i \frac{C_{ji}}{C_{j1}}$, $W_i = \frac{W'_i}{\sum_{i=1}^{n} W'_i}$ (18)

a- If all three cases (lower standards, upper standards and standards €[a,b] existed in n of Monitored Parameters, then $\sum_{i=1}^{n} W'_i$ is taken as the sum of the of the three cases as determined from the formula (13), (14) and one of three formulas (15) – (17) depending on the actual calculations.

Then, the product $W_i \frac{C_{ji}}{C_{j1}} = \frac{W'_i}{\sum_1^n W'_i} \frac{C_{ji}}{C_{j1}}$ correlated to the case 1 (formula 13).

$W_i \frac{C_{ji}}{C_{j1}} = \frac{W'_i}{\sum_1^n W'_i} \frac{1}{C_{ji} \times C_{j1}}$ correlated to case 2 (formula14).

$W_i \frac{C_{ji}}{C_{j1}} = \frac{W'_i}{\sum_1^n W'_i} \frac{1}{C_{ji} \times C_{j1}}$ correlated to case 3 (formula 15); or $W_i \frac{C_{ji}}{C_{j1}} = \frac{W'_i}{\sum_1^n W'_i} \frac{C_{ji}}{C_{j1}}$ (formula 16);

or $W_i \frac{C_{ji}}{C_{j1}} = \frac{W'_i}{\sum_1^n W'_i} \frac{1}{C_{j1}}$ (formula 17).

b- If all three cases in the item (a) do not exist, $\sum_{i=1}^{n} W'_i$ will be calculated for the cases happened correspondingly.

2) For the sum of group of parameters are not correspond with permitted standards $\sum_{i=1}^{k} W_i \frac{C_{ji}}{C_{j1}}$ at

any j. This time should consider the following cases:
Case 1: lower standards $C_{ji} \le C^*_{ji}$, consider only $C_{ji} > C^*_{ji}$, then $W_i \frac{C_{ji}}{C_{j1}} = \frac{W'_i}{\sum_1^n W'_i} \frac{C_{ji}}{C_{j1}}$ (formula 13).

Case 2: upper standards $C_{ji} \ge C^*_{ji}$, consider only

$C_{ji} < C^*_{ji}$, then $W_i \frac{C_{ji}}{C_{j1}} = \frac{W'_i}{\sum_1^n W'_i} \times \frac{1}{C_{ji} C_{j1}}$ (formula 14).

Case 3: standards in segment , consider only $C_{ji}<a$, $W_i \frac{C_{ji}}{C_{j1}} = \frac{W'_i}{\sum_1^n W'_i} \frac{1}{C_{ji} \times C_{j1}}$ (formula 15);

or $C_{ji}>b$, $W_i \frac{C_{ji}}{C_{j1}} = \frac{W'_i}{\sum_1^n W'_i} \frac{C_{ji}}{C_{j1}}$ (formula 16).

Note: To calculate the sums above, at first we need to select the standardized parameters.
In principle, standardized parameters may be selected by chance in sequence of monitoring parameters included n of analyzed parameters.
However, to clear the most toxicity of i parameters compared with other parameters, should choose the parameters i have the minimum permitted standards in the range of survey, and set this parameter equal to C_{11} with datum initially i=1, j=1.
The value of permitted standards of standardized parameters are coded as C^*_{11} in the survey point j=1 then.
Easy to see, the sum of weighting factors of the examined parameters equals a unit ($\sum_{i=1}^{n} W_i = 1$).

3. Applying TWQI to evaluate water quality in the coastal bay regions of Thanh Hoa province

3.1. Input Data

Input data for the calculations are based on the data obtained from monitoring water quality at six coastal bays: Can Bay (1, 2, 3); Sung Bay (4, 5, 6, 7); Truong Bay (8, 9); Trao Bay (10, 11, 12); Ghep Bay (13, 14, 15, 16) and Bang Bay (17, 18, 19, 20).

Total number of monitoring points (sampling for analysis or using quick measurement equipment) is 20.

The numbers in parenthesis against each location represents the order of Monitoring Points (j).
The number of parameters considered (n) is 13 (pH, TSS, DO, NH_4^+, As, Cd, Pb, Cr^{3+}, Cu, Zn, Mn, Fe, Hg).

Three samples were taken at each Monitoring Point, the average of three samples taken for each parameter was used for calculation.

The data was collected and the results were released in 2011 under a project entitled "Integrated investigation and evaluation of coastal mangrove areas to serve the strategy for sustainable development of Thanh Hoa province up to 2020". The Center for Monitoring Research and Modelling Environment (CEMM), University of Natural Sciences, Hanoi, under the chairmanship of Professor Dr. Pham Ngoc Ho was responsible for this project.

3.2. Results

3.2.1. Rating Scale

Applying TWQI Method, with *n=13*, from table (1) we were able to formulate the Water Quality Rating Scale. And applying CWQI, the Water Quality Rating Scale is predefined and fixed regardless of the number of parameters monitored. There are illustrated in Table 3.

3.2.2. Formula for calculation

- This is calculated by applying:

$$TWQI = 100 \times (1 - \frac{\sum_{i=1}^{k} W_i \frac{C_{ji}}{C_{j1}}}{\sum_{i=1}^{n} W_i \frac{C_{ji}}{C_{j1}}}) \quad \text{(formula 11)}$$

Hg was selected as standard parameters with C^*_{11} =0,001 mg/L (unique parameters compared with the remaining

Table 3. Total Water Quality Rating Scale, where *n=13* and CWQI Water Quality Rating Scale

TWQI			Water Quanlity	CWQI	Water Quality	Rating
92	<TWQI≤	100	Excellent	95-100	Excellent	A
69	< TWQI ≤	92	Good	80-94	Good	B
46	< TWQI ≤	69	Moderate	65-79	Fair	C
8	< TWQI ≤	46	Poor	45-64	Marginal	D
0	≤ TWQI ≤	8	Very Poor	0-44	Poor	E

parameters according to QCVN: 10/2008/BTNMT used for aquaculture, aquatic conservation).

- CWQI was calculated by formula (based on CCME 2001): $CWQI = 100\text{-}(\frac{\sqrt{F_1^2+F_2^2+F_3^2}}{1,732})$

in which $F_1 = \frac{a}{n}\times 100$; $F_2 = \frac{b}{m}\times 100$.

Here a, b – the number of parameters exceeded the permitted standards and analysis samples beyond permitted standards, correlatively; n, m - number of parameters and corresponding analysis samples.

$F_3 = \frac{nse}{0,01nse+0,01}$ - exceed standard deviation (Quantification of analysed values not consistent with permitted standards).

nse - The average value calculated through two steps:

Step 1: Calculate ex_i

i. Lower standard, just consider $C_i > C_i^*$, $ex_i = \frac{C_i}{C_i^*}\text{-}1$

ii. Upper standard, just consider $C_i < C_i^*$, $ex_i = \frac{C_i^*}{C_i}\text{-}1$

iii. Permitted standard € [a,b]: $ex_i = \frac{a}{C_i}\text{-}1$, if Ci<a; $ex_i = \frac{C_i}{b}\text{-}1$, if Ci>b.

Step 2: Calculate the average of the nse:

$$nse = \frac{1}{m}\sum_{i=1}^{b} ex_i$$

3.2.3. Calculation results and comments

Results of calculation using TWQI and CWQI are illustrated in Table 4.

Under TWQI, Table 4 illustrates the water quality in ranges "Moderate" and "Good" were observed at 15% of the Monitoring Points, whilst 85% recorded "Poor" quality, consistent with real observed data. For example, at Monitoring Point (j=10), just one parameter (TSS) exceeded the permitted standard by 2.7 times; the remaining 12 parameters were consistent with permitted standards. It therefore followed that the water quality was good. At Monitoring Point (j=3), three parameters exceeded permitted standards (TSSx2.2; NH_4^+x1.2 and Mnx1.4); At Monitoring Point (j=9), TSS exceeded permitted standards by three times and NH_4^+ by 1.1 times. Unsurprisingly, the water quality at both these Monitoring Points returned only moderate readings. On the other hand, by using CWQI, water quality at 100% of Monitoring Points is poor. The reason for the difference between the two methods is the fact that the assessment thresholds used in creating the CWQI were predefined and did not take into account the weighting factors (W_i) of the parameters examined. The WQI method (US) selected only nine typical parameters, of which only two (DO, TSS) coincided with the observation data of the project, It therefore does not guarantee reliability for purposes of comparison and collation.

For the method proposed by Department of Environment of Vietnam, only three parameters (pH, DO and NH_4^+) coincide with the observation data, and since it is intended to apply only to the continental surface water, it is not possible to compare or collate here.

4. Conclusion

The water quality depends on the physicochemical property of each parameter, which is regulated by the permitted standards set by the governments of

Table 4. Results of water quality rating in the coastal bays of Thanh Hoa province in 2011

j	TWQI		CWQI		j	TWQI		CWQI	
	TWQI	Water Quality	CWQI	Water Quality		TWQI	Water Quality	CWQI	Water Quality
1	35.596	Poor	22.979	Poor	11	39.208	Poor	23.476	Poor
2	43.648	Poor	24.596	Poor	12	39.279	Poor	24.292	Poor
3	52.185	Moderate	27.544	Poor	13	24.243	Poor	20.423	Poor
4	32.028	Poor	21.46	Poor	14	20.285	Poor	18.236	Poor
5	32.777	Poor	21.042	Poor	15	22.303	Poor	19.206	Poor
6	34.167	Poor	22.253	Poor	16	18.081	Poor	18.94	Poor
7	33.25	Poor	21.189	Poor	17	17.544	Poor	18.879	Poor
8	23.934	Poor	21.042	Poor	18	20.059	Poor	19.213	Poor
9	63.333	Moderate	29.699	Poor	19	24.41	Poor	19.016	Poor
10	70.555	Good	31.628	Poor	20	20.807	Poor	19.473	Poor

individual countries. The Total Water Quality Index (TWQI) method has advantages in total consideration to the toxicity of each parameter attaching with corresponding weighting factor and the hierarchical scales depending on monitoring parameters were all calculated by theoretical formulae thus giving it a scientific basis and hence more appropriate in real life situations.

Application of the Total Water Quality Index to assess water quality in the coastal bay regions of Thanh Hoa province, the results show that the water quality in there do not satisfy the criteria set for aquaculture. For this to happen, it will be necessary to establish the reasons for the poor water quality and only then remedial action can be taken. The introduction of breeding grounds will then be possible.

References

Canadian Water Quality Guidelines for the Protection of Aquatic life. CCME Water Quality Index 1.0 Technical Report. Canadian Council of Ministers of the Environment. 2001.

Pham Ngoc Ho. Weighted and Standardized Total Environmental Quality Index (TEQI) Approach in Assessing Environmental Components (Air, Soil and Water). DAAD, Proceedings of International Conference on Environmental Planning, Land Use Change and Monitoring, Hanoi. October 2011; 58-67.

Vietnam Environment Administration. Method for calculating the water quality index (WQI), Hanoi. 2010.

Wayne RO. (Ed.). Environmental Indices. Theory and Practice. Ann Arbor Science Publishes Inc, 1978.

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