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The Simplification of Doe Water Quality Index Calculation Procedures Using Graphical Analysis

[1]Gatot Eko Susilo and [2]Rina Febrina

[1]Department of Civil Engineering The University of Lampung Bandar Lampung, Indonesia
[2]Department of Civil Engineering Malahayati University Bandar Lampung, Indonesia

Abstract: The objective of water quality index calculation is to change complex water quality data into information that is understandable and useable by the public. In other word, water quality index is a tool used to summarize large amounts of complex, highly technical water quality data into a simple, easy-to-understand message. There are various water quality index calculation method developed in the world. One of them is the water quality index calculation method developed by Department of Environment (DOE) Malaysia. This method has been successfully applied to measure water quality for 462 rivers in Malaysia. The calculation involved six water parameters which are DO, BOD, COD, AN, SS, and pH. The procedure of calculation consists of 3 steps: to identity sub-index (SI) equation based on the value of parameter, to calculate sub-index (SI) of every parameter, and to calculate water quality index. This study aims to simplify the procedure of DOE water quality index calculation using graphical application. Using this method, the procedure of calculation can be cut down into two steps only. This graphical method is very useful for calculating water quality index without computer or any complex equations. The method has been successfully applied for water samples for Belau Kuripan River of Bandar Lampung, Indonesia. There is good agreement between result of calculation produced by conventional method and the one produced by graphical method for the sample.

Key words: water quality index; simplification; graphical analysis.

INTRODUCTION

All people in the world know that water is one of primary need to live. However, not many people recognize and aware about the condition and the quality of water they have nowadays. Water pollution increases day by day in many places in the world. On the other hand the availability of water supply decreases continuously. Based on the circumstance, water quality in many parts in the world is dropped continuously. Water quality is always an important and interesting topic to discuss. Problems in water quality in the world become global issues that need to be solved quickly.

Water quality is one of the most important factors that must be considered when evaluating the sustainable development of a region. However, to measure quality of water is not easy. The concept of water quality is complex because so many factors have influence in it (Cordoba, 2010). To handle this kind of problem, a method called Water Quality Index (WQI) was created. Water quality index is a risk communication tool used to describe the status of water by translating a large amount of non-commensurate data into a single value (

Ott, W.R. 1978). Water quality indices are intended to provide a simple and understandable tool for managers and decision makers on the quality and possible uses of sample of water body (Bordalo, 2001). WQI provides a single number (like a grade) that expresses overall water quality at a certain location and time based on several water quality parameters. The objective of an index is to turn complex water quality data into information that is understandable and useable by the public (BASIN, 2005). There are several methods have been proposed to obtain synthetic index expressing the environmental quality of natural resources including water. Such methods differ from each other in many characteristics such as environmental parameters, normalization functions, and aggregation functions in order to be made suitable for specific situations (Barbiroli, 1992).

In United States several WQI methods have been developed (UNEP - GEMS, 2003). A commonly-used water quality index (WQI) was developed by the National Sanitation Foundation (NSF) in 1970 (Brown, 1970).

Corresponding Author: Gatot Eko Susilo, Department of Civil Engineering The University of Lampung Bandar Lampung, Indonesia
E-mail: gatot@unila.ac.id

Kim and Cardone created a WQI that evaluates changes in water quality over time and space (Kim, 2005). Tsegaye developed a chemical WQI based on data from 18 streams in one lake basin in northern Alabama that summed the concentration of seven water quality parameters (total nitrogen, dissolved lead, dissolved oxygen, pH, and total, particulate and dissolved phosphorus) after standardizing each observation to the maximum concentration for each parameter (Tsegaye, 2006). The Canadian Water Quality Index (CWQI) compares observations to a benchmark, where the benchmark may be a water quality standard or site specific background concentration (F. Khan, 2003; CCME, 2001; Lumb, 2006). In Taiwan, WQI was developed as an index of river water quality. It is a multiplicative aggregate function of standardized scores for temperature, pH, toxic substances, organics (dissolved oxygen, BOD, ammonia), particulate (suspended solids, turbidity), and microorganisms such as faecal coliforms (Liou, 2004). Sargaonkar and Deshpande have developed the Overall Index of Pollution (OIP) for Indian rivers based on measurements and subsequent classification of pH, turbidity, dissolved oxygen, BOD, hardness, total dissolved solids, total coliforms, arsenic, and fluoride (Sargaonkar, 2003).

In Southeast Asia regions, the most recognized WQI maybe DOE WQI. The WQI is developed was developed by the Department of Environment of Malaysia (Sari and Omar, 2008). DOE WQI calculation has been used as standard calculation for water quality in Water Quality Monitoring Program in Malaysia (Rahman, Z.A., 2002). Until today, DOE WQI has been employed to measure water samples from 902 manual stations in 120 basins (462 rivers) in Malaysia. This WQI method is quite powerful to measure water quality samples yet the calculation procedure is not quite easy to undertake without computer assistance. This paper aims to develop graphical calculation method in order to find easier procedure of DOE WQI calculation.

DOE WQI Calculation Procedure:

There are six water parameters involve in the DOE WQI calculation. They are (Sari, 2008):

- Dissolved Oxygen (DO) in % of saturation unit
- Biological Oxygen Demand (BOD) in mg/L unit
- Chemical Oxygen Demand (COD) in mg/L unit
- Ammoniacal Nitrogen (AN) in mg/L unit
- Suspended Solid (SS) in mg/L unit
- pH with no unit.

The formula used for calculating DOE WQI is developed by the Department of Environment of Malaysia. The formula is described as follows (DOE., 2001):

$$WQI = 0.22SIDO + 0.19SIBOD + 0.16SICOD + 0.15SIAN + 0.16SISS + 0.12SIpH \quad (1)$$

Where:

- SIDO=Sub-index DO
- SIBOD =Sub-index BOD
- SICOD =Sub-index COD
- SIAN =Sub-index NH3N
- SISS =Sub-index SS
- SIpH =Sub-index pH

Every sub-index is calculated based on the equation in certain condition which is:

- SIDO
- SIDO = 0 for $x \leq 8$
- SIDO = 100 for $x \geq 92$
- SIDO = $-0.395 + 0.030x^2 - 0.00020x^3$ for $8 < x < 92$
- SIBOD
- SIBOD = $100.4 - 4.23x$ for $x \leq 5$
- SIBOD = $108 * \exp(-0.055x) - 0.1x$ for $x > 5$
- SICOD

  SICOD = $-1.33x + 99.1$ for $x \leq 20$

  SICOD = $103*\exp(-0.0157x) - 0.04x$ for $x > 20$
- SIAN

  SIAN = $100.5 - 105x$ for $x \leq 0.3$

  SIAN = $94*\exp(-0.573x) - 5 * |x - 2|$ for $0.3 < x < 4$; SIAN = 0 for $x \geq 4$
- SISS

  SISS = $97.5*\exp(-0.00676x) + 0.05x$ for $x \leq 100$

SISS = 71*exp (-0.0061x) - 0.015x for $100 < x < 1000$
SISS = 0 for $x \geq 1000$

- SIpH
  SIpH = $17.2 - 17.2x + 5.02x^2$ for $x < 5.5$
  SIpH = $-242 + 95.5x - 6.67x^2$ for $5.5 \leq x < 7$
  SIpH = $-181 + 82.4x - 6.05x^2$ for $7 \leq x < 8.75$
  SIpH = $536 - 77.0x + 2.76x^2$ for $x \geq 8.75$.

General rating scale for the DOE WQI is between 0 and 100. The interpretation of the value applied in some water resources development purposes is described below:

- For general use of water:
  $0 \leq x < 60$ = very polluted water
  $60 \leq x < 80$ = slightly polluted water
  $x > 80$ = clean water.
- For classification of water:
  $0 \leq x < 40$ = Class V
  $40 \leq x < 50$ = Class IV
  $60 \leq x < 80$ = Class III
  $80 \leq x < 90$ = Class II
  $x > 90$ = Class I.
- For public water supply:
  $0 \leq x < 40$ = not acceptable for public water supply
  $40 \leq x < 50$ = doubtful for public water supply
  $60 \leq x < 80$ = needs expensive treatment for public water supply
  $80 \leq x < 90$ = needs minor purification for public water supply
  $x > 90$ = no need treatment for public water supply
- For recreation water:
  $0 \leq x < 20$ = not acceptable for recreation
  $20 \leq x < 30$ = obvious pollution appearing, still not acceptable for all recreation; $30 \leq x < 40$ = only for boating
  $40 \leq x < 50$ = doubtful for water contact; $50 \leq x < 70$ = acceptable for water contact but needs bacteria count
  $x > 70$= acceptable for all water sport.
- For fisheries:
  $0 \leq x < 30$ = not acceptable for fisheries
  $30 \leq x < 40$ = only for coarse fish
  $40 \leq x < 50$ = only for handy fish
  $50 \leq x < 60$ = doubtful for sensitive fish
  $60 \leq x < 70$ = marginal for trout
  $x > 70$ = acceptable for all fish.
- For navigation:
  $0 \leq x < 30$ = not acceptable for navigation
  $30 \leq x < 40$ = obvious pollution appearing
  $x > 50$ = acceptable for all navigation.
- For water transportation:
  $0 \leq x < 10$ = not acceptable for water transportation
  $x > 10$ = acceptable for water transportation.

III. The Calculation of Doe Wqi Using Graphical Method :

Graphical method for calculating DOE WQI is derived from general calculation procedures in (1). In the graphical method, the general equation of WQI calculation is changed into:

WQI = SIDO'+SIBOD'+SICOD'+SIAN'+SISS'+SIpH' (2)

The value of SIDO', SIBOD', SICOD', SIAN', SISS', and SIpH' is derived from the value SIDO, SIBOD, SICOD, SIAN, SISS, and SIpH multiplied by their coefficient. The calculation procedure of SIDO, SIBOD, SICOD, SIAN, SISS, and SIpH combined with the multiplication with their coefficient is described in the graphical presentation. The graphs are presented in the Fig. 1 to Fig 6. By using the graph of SIDO', SIBOD', SICOD', SIAN', SISS', and SIpH', the calculation procedures of WQI can be simplified and furthermore it can be undertaken without the assistance of computer.

IV. The Application Of Graphical Method In DOE WQI Calculation:

Graphical method of DOE WQI has been applied to calculate water quality index of water sample obtained from Belau Kuripan River in Bandar Lampung Indonesia. The location of water sampling is illustrated in the figure X. Water of this river is used for some purposes such as cleaning and sanitizing by the people living in the surrounding areas. Based on this condition, it is necessary to know whether the water is qualified enough for water domestic used.

The water sample is 20 liter of water and analyzed in Industrial Department of Lampung Province. The data obtained from water sample related to the DOE WQI calculation is described below:

The ordinary or numerical method of water quality index calculation is used to find water quality of the water sample. Based on the data, water quality index of the sample is calculated using the procedure as follows:

For DO = 35%, the formula used is the one for $8 \leq x < 92$. SIDO = $-0.395 + 0.030x^2 - 0.00020x^3$, hence SIDO = 27.78

For BOD = 10.6, the formula used is the one for $x > 5$. SIBOD = 108 * exp (-0.055x) - 0.1x , hence SIDO = 59.23

- For COD = 38.69, the formula used is the one for $x > 20$. SICOD = 103*exp (-0.0157x) - 0.04x, hence SICOD = 54.56
- For AN = 0.231, the formula used is the one for $x \leq 0.3$. SIAN = 100.5 - 105x, hence SIAN = 76.25
- For SS = 274.8, the formula used is the one for $100 < x < 1000$. SISS = 71*exp (-0.0061x) - 0.015x, hence SISS = 9.16
- For pH = 6.8, the formula used is the one for $5.5 \leq x < 7$. SIpH = $-242 + 95.5x - 6.67x^2$ hence SipH = 98.98

Following (1), the water quality index value then calculated as:

$$WQI = 0.22*27.78 + 0.19*59.23 + 0.16*54.56 + 0.15*76.25 + 0.16*9.16 + 0.12*98.98 \quad (3)$$

hence WQI = 50.33.

Using graphical analysis, the calculation of water quality index for water sample from Belau Kuripan River is undertaken as follows:

- For DO = 35% hence SIDO' = 6.00
- For BOD = 10.6 hence SIDO' = 11.00
- For COD = 38.69 hence SICOD'= 8.80
- For AN = 0.231 hence SIAN' = 11.50
- For SS = 274.8 hence SISS' = 1.30
- For pH = 274.8 hence SipH' = 11.80

The water quality index value then calculated as:

$$WQI = 6.00 + 11.00 + 8.80 + 11.50 + 1.30 + 11.80 \quad (4)$$

hence WQI = 50.40.

Both calculation methods applied produced relatively similar value of water quality index. For the case of water sample from Belau Kuripan River, the accuracy of the graphical method result can be calculated as follows:

$$Eff = 100 - (|WQI_{num} - WQI_{graph}| / WQI_{num})(5)$$

Where Eff is accuracy of the method, WQI_{num} is the WQI value produced by ordinary or numerical method, and WQI_{graph} is the value produced by graphical method. Based on the formula the accuracy of the graphical method is 99.99%. This fact indicates that the graphical method developed is accurate enough to be used in DOE water quality index calculation.

Table I: Result of Water Sample Analysis

No.	Parameter	Unit	Data
1	DO	% saturated	35.0
2	BOD	mg/l	10.6
3	COD	mg/l	38.69
4	AN	mg/l	0.231
5	SS	mg/l	274.8
6	pH	-	6.8

***Conclusion*:**

The calculation procedure of DOE WQI using graphical method has been analyzed. The purpose of developing the graphical method for calculating WQI is to help the users analyzing WQI by various methods. The graphical method provides facility that is easy for everyone, regardless their skill in computer or mathematics. The procedure of WQI calculation using this method is very short and simple if compared to the one using ordinary or numerical method. However, it is quite vague to state that graphical method is better than numerical method in calculating DOE WQI. Both methods have their own strength and weakness. For the best practice, calculation result from each method can be used to check the one produced by another method.

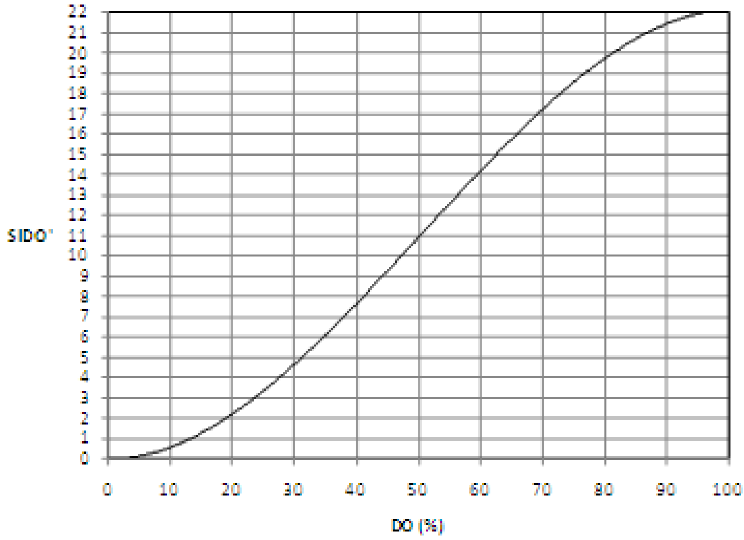

Fig. 1: SIDO' graph.

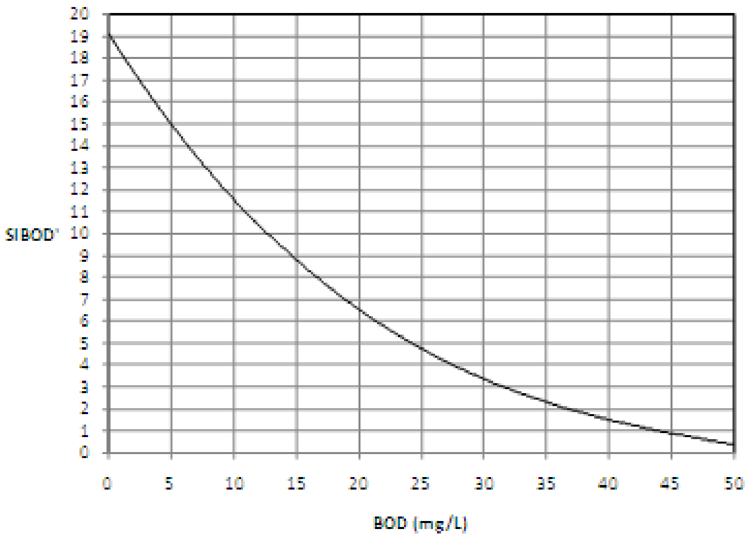

Fig. 2: SIBOD' graph.

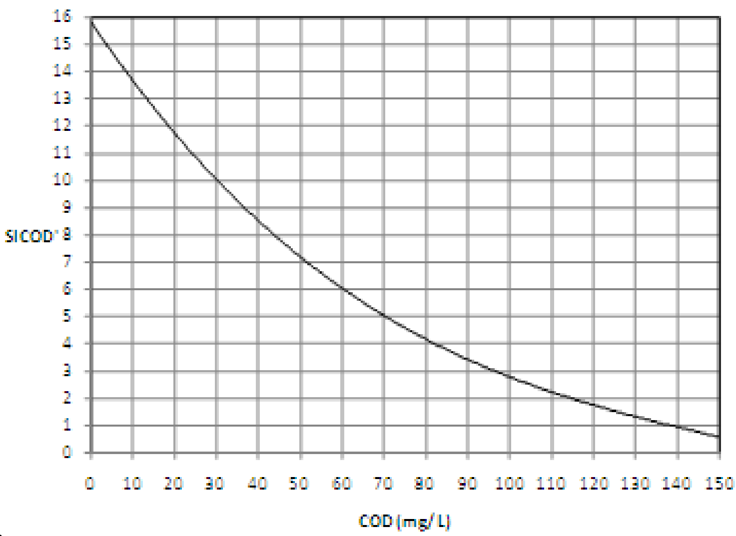

Fig. 3: SICOD' graph.

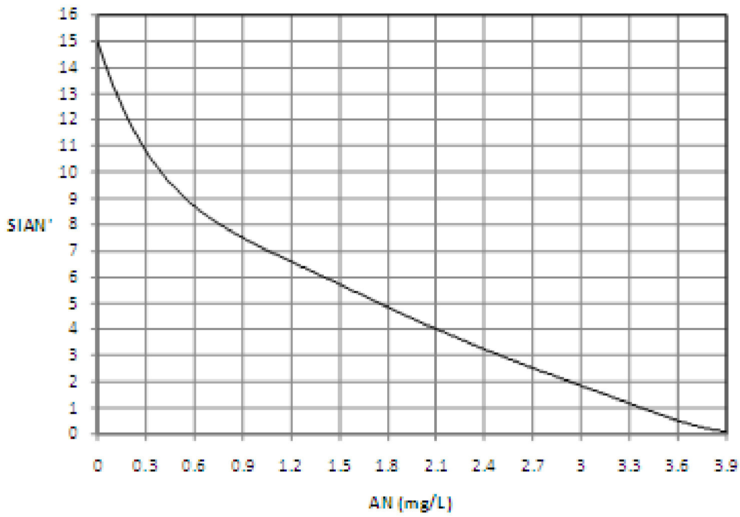

Fig. 4: SIAN' graph.

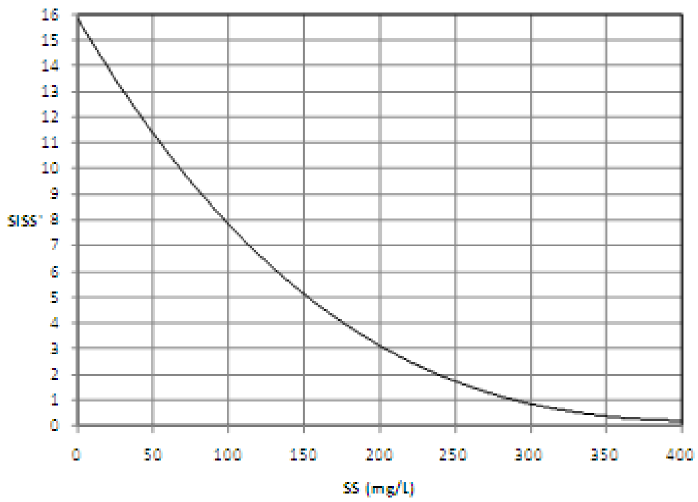

Fig. 5: SISS' graph.

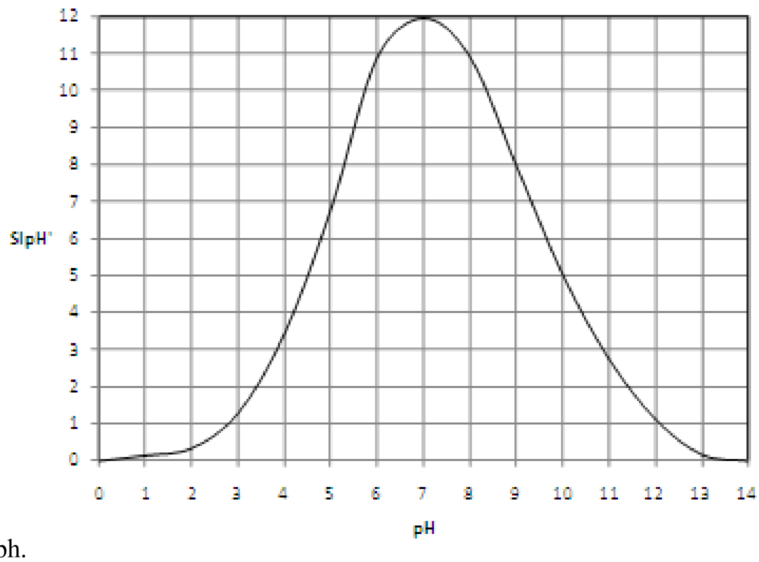

Fig. 6: SIDO' graph.

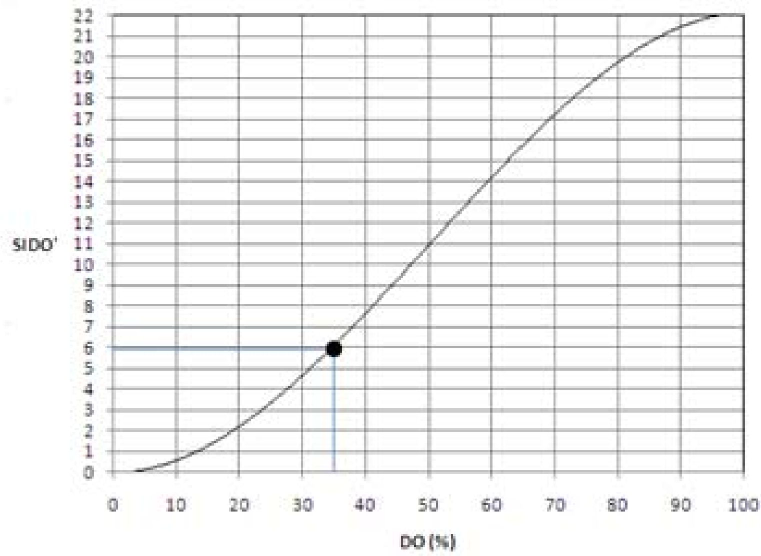

Fig. 7: The example of graph graphical method to find the value of SIDO'

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