

**COMPARISON OF WATER QUALITY INDEX (WQI) BETWEEN DOE
METHOD AND HARKIN'S INDEX**

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To my beloved father, Lim Kon Pau
and
beloved late mother, Chong Moi

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ABSTRACT

Water quality index (WQI) provides a convenient means of summarizing large numbers of water quality data, facilitating its communication to a general audience and will aid in establishment of priorities by providing quantitative data on overall water quality in regularly sampled water bodies. Large volume of continuous time series water quality data can be readily available due to automated continuous water quality monitoring of DOE/ASMA. Raw data obtained from DOE/ASMA for Sungai Rompin, Skudai and Klang from year 1998 to 2002 is analyzed using DOE WQI method and Harkin's WQI method. Average WQI from the study are: Sungai Rompin DOE 81.65 / Harkins 9.76; Sungai Skudai DOE 67.33 / Harkins 10.80 ; Sungai Klang DOE 51.54 / Harkins 9.63. DOE WQI show that Sungai Rompin is clean river, Sungai Skudai is slightly polluted and Sungai Klang is polluted river. However, Harkin's WQI is not able to provide the observation as DOE WQI. This indicate that DOE WQI is more sensitive to data changes and provide better insight of river condition compared to Harkin's WQI. Correlation value, r^2 calculated using Microsoft excel obtained for Sungai Rompin is 0.25, Sungai Skudai is 0.59 and Sungai Klang is 0.43. However, weak or marginally significant correlation does not necessary indicate lack of agreement as to what constitutes good or poor water quality because of Harkin's WQI calculation. Harkin's WQI dependant on the control vector chosen for the S_n calculation. This is the major hindrance of Harkin's WQI because the S_n data need to be computed whenever there is new data added to be computed. The control vector chosen also will affect the overall observation because by using different data as the control vector, the whole Harkin's WQI data will be change. DOE WQI is more dependants on dissolved oxygen (DO) data because it has the highest weighing compared to other parameter. Current DOE WQI method still the preferred simplify method to share data with public. However, there is way to further improve on the water quality information to the authority or public for management.

ABSTRAK

Indek kualiti air (WQI) adalah satu cara yang mudah untuk meringkaskan data kualiti air yang banyak, memudahkan komunikasi dengan orang awam dan membantu program pengendalian kualiti air dalam pemilihan. Data kualiti air yang banyak sedia ada disebabkan terdapat pengumpulan data dari masa ke semasa dengan sistem automatik kualiti air DOE/ASMA. Data kasar diperolehi dari DOE/ASMA untuk Sungai Rompin, Skudai dan Klang dari tahun 1998 ke 2002, dianalisa dengan menggunakan cara pengiraan DOE WQI dan Harkin WQI. Purata WQI dari pengiraan adalah: Sungai Rompin DOE 81.65 / Harkins 9.76; Sungai Skudai DOE 67.33 / Harkins 10.80 ; Sungai Klang DOE 51.54 / Harkins 9.63. DOE WQI menunjukkan bahawa Sungai Rompin adalah bersih, Sungai Skudai sederhana tercemar dan Sungai Klang adalah tercemar. Walaubagaimanapun, Harkin's WQI tidak dapat menunjukkan pemerhatian yang sama. Ini menunjukkan DOE WQI adalah lebih sensitif kepada data dan memberi keadaan sungai yang lebih tepat berbanding dengan Harkin's WQI. Data kolerasi, r^2 dikira menggunakan 'Microsoft excel' untuk Sungai Rompin adalah 0.25, Sungai Skudai adalah 0.59 dan Sungai Klang adalah 0.43. Walaubagaimanapun, korelasi yang lemah tidak semestinya menunjukkan kualiti air yang sebenar disebabkan pengiraan Harkin WQI yang bergantung kepada vektor kontrol yang dipilih untuk pengiraan Sn. Ini adalah satu halangan besar untuk indek Harkin kerana data Sn perlu dikira setiap kali data yang baru ditambah. Vektor kontrol yang dipilih juga akan memberi kesan kepada pemerhatian keseluruhannya kerana dengan vektor control yang berlainan, data Harkin WQI akan bertukar. DOE WQI adalah lebih bergantung kepada data oksigen terlarut (DO) dan menyebabkan ianya memberi nilai yang paling tinggi berbanding dengan parameter lain. Cara pengiraan sekarang menggunakan DOE WQI masih digalakkan sebagai satu cara untuk berkongsi data terutama dengan orang awam. Walaubagaimanapun, terdapat cara yang lebih baik untuk terus memperbaiki informasi kualiti air untuk penguatkuasa dan orang awam.

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LIST OF SYMBOLS

P	-	Production
R	-	Respiration
C	-	Characteristic by the appropriate weighting factor (W)
W	-	Weighting factor
M_1	-	Temperature
M_2	-	Obvious pollution
μ	-	Micro
x	-	Concentration in mg/l for all parameters except pH
R_i	-	Variance
p	-	Number of parameters being used
n	-	Number of observations plus the number of control points
k	-	Number of ties encountered
R_c	-	Rank of the control value
S_n	-	Standardized distance
r^2	-	Correlation

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CHAPTER 1

INTRODUCTION

Water is the essential need for life. The demand for clean and portable water has increased tremendously due to rapid development and a growing population. To preserve water quality and quantity, it is necessary to obtain data from regularly sampling at predetermined stations for in-situ and laboratory analysis. This information permits one to establish priorities with regards to preservation and quality control in the country.

Rivers are the most important freshwater resource for man. Major river water uses such as sources of drinking water supply, irrigation of agricultural lands, industrial and municipal water supplies, industrial and municipal waste disposal, navigation, fishing, boating and body contact recreation.

Upstream use of water must only be undertaken in such a way that it does not affect water quantity, or water quality, for downstream users. Use of river water is, therefore, the subject of major political negotiations at all levels. Consequently, river water managers require high quality scientific information on the quantity and quality of the waters under their control. Provision of this information requires a network of river monitoring stations in order to:

- a) establish short- and long-term fluctuations in water quantity in relation to basin characteristics and climate;
- b) determine the water quality criteria required to optimize and maintain water uses;

- c) determine seasonal, short- and long-term trends in water quantity and quality in relation to demographic changes, water use changes and management interventions for the purpose of water quality protection.

As with all freshwater systems, river quality data must be interpreted within the context of a basic understanding of the fluvial and river basin processes with control the underlying characteristics of the river system. Similarly, the design of the monitoring network, selection of sampling methods and variables to be measured must be based on an understanding of fluvial processes as well as the requirement for water use.

1.1 Major water quality issues in rivers

1.1.1 Changes in physical characteristics

Temperature, turbidity and total suspended solids (TSS) in rivers can be greatly affected by human activities such as agriculture, deforestation and the use of water for cooling.

1.1.2 Faecal contamination

Faecal contamination is still the primary water quality issue in rivers, especially in many developing countries where human and animal wastes are not yet adequately collected and treated. Although this applies to both rural and urban areas, the situation is probably more critical in fast-growing cities where the population growth rate still far exceeds the rate of development of wastewater collection and treatment facilities.

1.1.3 Organic matters

The release into rivers of untreated domestic or industrial wastes high in organic matter results in a marked decline in oxygen concentration (sometimes resulting in anoxia) and a release of ammonia and nitrite downstream of the effluent input. The effects on the river are directly linked to the ratio of effluent load to river water discharge. The most obvious effect of organic matter along the length of the river is the “oxygen-sag curve” which can be observed from a few kilometres to 100 km downstream of the input. When monitoring for the effects of organic matter pollution, stations should be located in the middle of the oxygen-sag curve (if the worst conditions are being studied) or at the beginning of the recovery zone, depending on the objectives of the programme (Chapman, 1996).

1.1.4 River eutrophication

Eutrophication which is nutrient enrichment leading to increased primary production was observed mostly in lakes and reservoirs. Eutrophication can result in marked variations in dissolved oxygen and pH in rivers during the day and night. During the daylight, primary production (P) far exceeds the bacterial decomposition of algal detritus (R), and O₂ over-saturation may reach 200 per cent or more, with pH values in excess of 10 during the early afternoon. During the night, this pattern is reversed and O₂ levels may fall to 50 per cent saturation and the pH may fall below 8.5 (Figure 1.1) (Chapman, 1996).

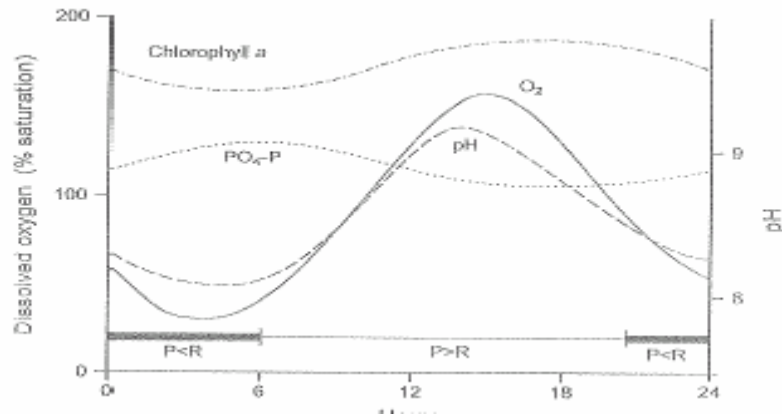


Figure 1.1 : Theoretical variations in O_2 and pH associated with algal production in a eutrophic river - P production; R respiration (Chapman, 1996)

When respiration levels become greater than the primary production (i.e. $R > P$) in the downstream reaches of rivers, or in their estuaries, the O_2 concentration can decline dramatically. Occasionally this can result in total anoxia, as in some turbid estuaries during the summer period.

Diel variations in water quality cause major problems for monitoring and assessment of eutrophic rivers. Sampling at a fixed time of the day can lead to a systematic bias in recorded O_2 and pH levels. Although chlorophyll and nutrients may also show some fluctuations in concentrations, these are generally within 20 per cent of the daily mean.

1.1.5 Salinisation

Increased mineral salts in rivers may arise from several sources: (i) release of mining wastewaters (ii) certain industrial wastewaters (iii) increased evaporation and evapotranspiration in the river basin resulting from reservoir construction, irrigation returns, etc.

1.1.6 Acidification

Acidification can occur in running waters as a result of: (i) direct inputs of acidic wastewaters from mining or from specific industries, either as point sources (e.g. sewers) or diffuse sources (e.g. leaching of mine tailings), and (ii) direct inputs through acidic atmospheric deposition, mainly as nitric and sulphuric acids resulting mostly from motor exhausts and fossil fuel combustion. In the latter case, acidification of surface waters may only take place if the buffering capacity of the river basin soil is very low. Low buffering capacity mainly occurs in areas of non-carbonate detrital rocks, such as sandstones, and of crystalline rocks such as granites and gneisses.

1.1.7 Trace elements

Trace element pollution results from various sources, mostly: (i) industrial wastewaters such as mercury from chlor-alkali plants, (ii) mining and smelter wastes, such as arsenic and cadmium, (iii) urban run-off, particularly lead, (iv) agricultural run-off (where copper is still used as a pesticide), (v) atmospheric deposition, and (vi) leaching from solid waste dump.

1.1.8 Nitrate pollution

Urban wastewaters and some industrial wastes are major sources of nitrate and nitrite. However, in regions with intensive agriculture, the use of nitrogen fertilizers and discharge of wastewaters from the intensive indoor rearing of livestock can be the most significant sources.

Heavy rain falling on exposed soil can cause substantial leaching of nitrate, some of which goes directly into rivers, but most of which percolates into the groundwater from where it may eventually reach rivers if no natural denitrification occurs.

1.1.9 Organic micropollutants

Organic micropollutants (mostly synthetic chemicals manufactured artificially) are becoming a critical water quality issue in developed and developing countries. They enter rivers : (i) as point sources directly from sewers and effluent discharges (domestic, urban and industrial sources), (ii) as diffuse sources from the leaching of solid and liquid waste dumps or agricultural lan run-off, or (iii) indirectly through long-range atmospheric transport and deposition. Agriculture is a major source of new chemical pollutants to rivers, such as pesticides. The approach to monitoring these substances depends mostly on their properties, i.e. volatility, water solubility, solubility in lipids, photodegradation, biodegradation, bioaccumulation, etc.

1.1.10 Changes in river hydrology

Many human activities, directly or indirectly, lead to modification of the river and its valley which produce changes in the aquatic environment without major changes in the chemical characteristics of the river water. Such changes can lead to loss of biological diversity and, therefore, biological monitoring techniques are most appropriate in these situations, supported by careful mapping of the changes in the river bed and banks.

Major modifications to river systems include changes to depth and width for navigation, flood control ponds, reservoirs for drinking water supply, damming for hydroelectric power generation, diversion for irrigation, and canalization to prevent loss of flood plains of agricultural importance due to river meandering. All of these affect the hydrology and related uses of the river system.

1.2 Water Resource Management in Malaysia

In Malaysia, the Department of Environment (DOE) started monitoring of river water quality in 1978, initially establish water quality baselines and subsequently to detect water quality changes and identify pollution sources. Samples had been regularly taken at predetermined stations for in-situ and laboratory analysis and data interpretation in terms of physico-chemical and biological characteristics.

The water quality appraisal is based on the Water Quality Index (WQI) consisting of parameters such as Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH₃N), Suspended Solids (SS) and pH. The WQI serves as a basis for environmental assessment of a watercourse in relation to pollution load categorization and designation of classes of beneficial uses as provided for under the Interim National Water Quality Standards for Malaysia (INWQS). (Department of Environment, 2005). INWQS is divided into 5 classes, Class 1 being the cleanest and Class V being the most polluted.

Table 1.1 : Definition of Classes for INWQS

Class		Uses
CLASS I	:	Conservation of natural environment Water Supply 1 – practically no treatment necessary (except by disinfection or boiling only). Fishery 1 – very sensitive aquatic species
CLASS IIA	:	Water Supply II – conventional treatment required. Fishery II – sensitive aquatic species
CLASS IIB	:	Recreational use with body contact
CLASS III	:	Water Supply III – extensive treatment required. Fishery III – common, of economic value, and tolerant species; livestock drinking
CLASS IV	:	Irrigation
CLASS V	:	None of the above

Table 1.2 : Excerpt of Interim National Water Quality Standards (INWQS)

PARAMETERS	UNIT	CLASS					
		I	IIA	IIB	III	IV	V
Ammoniacal Nitrogen	mg/L	0.1	0.3	0.3	0.9	2.7	>2.7
BOD	mg/L	1	3	3	6	12	>12
COD	mg/L	10	25	25	50	100	>100
DO	mg/L	7	5 - 7	5 - 7	3 - 5	<3	<1
pH		6.5 – 8.5	6 - 9	6 - 9	5 - 9	5 - 9	-
Colour	TCU	15	150	150	-	-	-
Elec. Conductivity	umhos/cm	1000	1000	-	-	6000	-
Floatables		N	N	N	-	-	-
Odour		N	N	N	-	-	-
Salinity (%)	%	0.5	1	-	-	2	-
Taste		N	N	N	-	-	-
Total Dissolved Solid	mg/L	500	1000	-	-	4000	-
Total Suspended Solid	mg/L	25	50	50	150	300	300
Temperature (C)	°C	-	Normal +2°C		Normal +2°C	-	-
Turbidity (NTU)	NTU	5	50	50	-	-	-
Faecal Coliform**	counts/100mL	10	100	400	5000 (20000) ^a	5000 (20000) ^a	-
Total Coliform	counts/100mL	100	5000	5000	50000	50000	>50000

Notes

N : No visible floatable materials or debris, No objectionable odour; No objectionable taste

* : Related parameters, only one recommended for use

** : Geometric mean

a : Maximum not to be exceeded

1.3 Study Area Overview

In 1960s onwards, efforts were made from a few individual to find a suitable, reliable and rapid manner of classifying a water body for different purposes, which led to the development of the “Water Quality Indices or Water Quality Index”. Since then, different indices have been developed (Horton, 1965; Harkins, 1974).

Water quality index provides a convenient means of summarizing complex water quality data and facilitating its communication to a general audience. Utilization of the water quality index will help staff, lawmakers, and the public to evaluate progress being made in water quality management programs and will aid in establishment of priorities by providing quantitative data on overall water quality in regularly sampled water bodies. The index should allow staff to readily interpret and evaluate regularly generated laboratory data, recognize trends or problem areas, and optimize sampling location and frequency.

1.4 Problem Statement

In Malaysia, automated continuous water quality monitoring of DOE/ASMA have proven to be cost effective means for measuring the real time water quality status of rivers. By this means, large volume of continuous time series water quality data can be readily available for more effective pollution control and for a better understanding of the dynamics of water quality changes in the river.

DOE has taken some steps in adopting a WQI system for the evaluation of the past and present water quality status, but there remain several important aspects to be studied further before effective application is possible.

Harkin's WQI calculation method is used to compare with DOE WQI because Harkin's method can be considered as the first type of water quality index calculation method and it has been used for studies since then.

DOE WQI is using six parameters whereas Harkins' WQI is using four parameters where three of the four parameters are the same as DOE WQI method. The calculation method also different which will provide insight of different findings based on different WQI method.

1.5 Importance of Study

The importance of this study draws parallel to the purpose of better understanding of water quality index and viewed in their proper context. The value of a water quality index scale is to impart information of trends in water quality in a non-technical manner and to help pinpoint river stretches which have altered significantly in quality and which, if necessary, can be investigated in greater detail.

A good water quality index will provide a clearer picture of the river water quality to public. Water quality index will act as indicators of water quality changes and also indicate the effects of these changes on potential water use. Large sum of money invested annually will be worthwhile since it will provide a meaningful usage.

Reducing a large quantity of data to a single number index will allow more meaningful comparison to be made and integrate the effects of the various pollutions presents. Single number also can be used as education to country's younger generation as one of the method to prevent further river pollution due to mankind.

1.6 Study Objectives

The objectives of this study as follows:

1. To interpret water quality raw data from ASMA using 2 types of WQI calculation methods i.e. Harkins method and DOE method;
2. To detect annual cycles and trends in the surface water quality;
3. To observe the WQI data and illustrate the importance of accurate WQI method used for information sharing to government and public.

1.7 Scope of Study

To achieve the preset objectives above, several goals are set:

1. Study the water quality status published by DOE yearly and identify three suitable river basin – clean, slightly polluted and polluted river basins;
2. Request data from ASMA for the above three river basins from year 1998 to 2002 on dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solid (SS), acidity/alkalinity (pH), ammoniacal nitrogen (NH₃-N) and total phosphate (PO₄);
3. Calculation of WQI using Harkins method and DOE method;
4. Analyze calculated data and compare 2 different index.