Establishment of Water Quality Indexes for Raw Water in the Water Supply

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Abstract

Over two decades, climate variability has caused a significant change in human well-being, particularly in the availability of water resources. The water shortage and insufficient water supply especially affect the quality of life in many ways. The Pollution Control Department (PCD) of the Metropolitan Waterworks Authority (MWA) has selected thirteen parameters considered essential as indicators of raw water suitability. The water quality of the Chao Phraya River at 18 PCD stations along the 379-km stretch from Chainat to Samutprakarn has been recorded for analysis and considered for inclusion in a Water Quality Index (WQI) that includes color, turbidity, Biochemical Oxygen Demand (BOD), Dissolved oxygen (DO), pH, Nitrate-Nitrogen (NO_3-N), Fe, Mn, Total Dissolved Solids (TDS), Total Phosphorous (TP), Electrical Conductivity (EC), salinity, and hardness. The WQI provides a single value for water quality suitability, is useful for the MWA in water supply production, and reflects the constituents that may be harmful to the consumer and the efficiency of production. For example, if the salinity in raw water is greater than 0.25 mg/l, the salt content of the water cannot be removed by the MWA system, resulting in a water supply with a salty flavor. Therefore, if the deteriorated water quality of raw water is predicted in advance, measured at a point upriver from the Samlae intake station, appropriate solutions can be put in place. Using PCD water quality records, the average WQI score of the Chao Phraya River in the rainy season is 74.63 and in the dry season is 78.37 (from a full score of 100). These values indicate the deterioration of raw water quality during the low flow period, a situation that the MWA should acknowledge and make periodical inspections to identify and control.

Keywords: MWA, Rating Curves of Water Quality Parameters, Surface Water Quality Standard, WQI, Water Supply Production.

1. INTRODUCTION

Water is an essential resource for living organisms in various ways. However, several human activities such as the excretion of waste in daily life and wastewater discharge from agricultural and industrial activities lead to the deterioration of water quality. Contamination of water sources causes the loss of water use benefits Pilailar and Urantinon (2019). As a result, the quality of life of living beings worsens.

To better understand the water quality in an area of interest, this should be determined by a combination of physical, chemical, and biological characteristics, and the integrated water situation should be evaluated using an appropriate technique, such as a Water Quality Index (WQI), the numerical summation of multiple water quality parameters into a single value. The WQI was calculated as a single value from multiple test results of water quality in a water basin by Horton (1965). It has since been widely applied for generating trends, evaluating, and communicating the overall water quality for the public to understand, and allowing comparisons among different watercourses or different locations in the same watercourse.

The WQI concept integrates all water quality parameters such as Biochemical Oxygen Demand (BOD) and Dissolved oxygen (DO) into scores that can indicate water quality for multiple purposes. The 4 steps for developing WQI are (1) selecting a set of water quality parameters of interest, (2) developing sub-indices-transforming the different units and dimensions of water quality parameters to a common scale, (3) assigning weights to the water quality parameters based on their relative importance to overall water quality, and (4) aggregating sub-indices to produce an overall index Boyacıoğlu (2009).

In Thailand, the WQI has been used to research and develop water quality standards for the Chao Phraya River at the raw water intake station of the MWA in Pathum Thani Province. The parameters were measured in physical, chemical, and biological properties. It was found that the water quality was satisfactory since the raw water was self-purified along the canal that transports the water to the production plant Thamkasem et al., (1986). However, at the production plant, turbidity, smell, color, and bacteria remain to be removed for making safe-drinking water, following World Health Organization (WHO) water quality standards guidelines World Health Organization (2011).

In 1995, the water quality management division of the Pollution Control Department (PCD) of the Metropolitan Waterworks Authority (MWA) modified the WQI of Brown Brown et al., (1970) to consider the basis of research in this field for evaluating the overall water quality in Thailand's rivers Simachaya (2000). Following their suggestions, unweighted WQI was applied for assessing the overall water quality by the PCD, in which all water quality parameters of interest were assumed to have the same level of importance. Before determining the WQI in each area, the values of each water quality parameter included in the WQI model are converted into sub-index scores between 0 and 100 using the rating curve technique developed for Thailand's rivers Landwehr (1979).

In 2007, a WQI was developed for the Chao Phraya River by selecting the data from seven water quality monitoring stations. Thirteen parameters were included in cluster type analysis (CA), factor analysis (FA), multiple regression, and statistical processes to analyze the data to select the parameters suitable for the setting of the WQI Prakirake et al., (2009).

Although WQI has been widely used in evaluating water quality in several countries, the usefulness of the WQI depends on its purpose. In 2015, an assessment of the water quality of the Ganges River in India using the WQI tool was undertaken, and the WQI values enabled an easy understanding of the trends of the water quality. The results pointed towards the requirement for urgent plans to prevent river water pollution. In 2018, Ahmed Hamdan created a WQI map based on Geographic Information System (GIS) for the Shatt Al-Arab River and its branches in Iraq to inform local authorities and convince them to take action Meher et al., (2015).

In Thailand, a WQI to measure the water quality situation of the six river basins was created by the PCD, referred to as the PCD-WQI which included eleven water quality parameters. A sampling station in Phra Nakhon Si Ayutthaya was the sampling point on the Chao Praya River. The PCD-WQI value was also able to be used to monitor the management of water resources for sustainability Tiyasha et al., (2020), and has been used to assess the chemical, physical, and microbiologic features of water bodies in temperate latitudes and was developed as an ecosystem-specific WQI, termed the ES-WQI Gradilla-Hernández et al., (2020).

In the current study, a set of water quality parameters was used to measure raw water quality in the Chao Phraya River at nine PVD stations along 180 kilometers of the river from Chainat to the Samlae raw water pumping station in Pathum Thani province. The variation in raw water quality due to the seasonal change has been a concern. To measure this seasonal variation, water quality assessment was divided into the rainy season, June to September, and the dry season, October to February. Based on the surface water quality standard of the PCD and the drinking water quality standards of the WHO water quality standards guidelines, 13 water quality parameters including color, turbidity, BOD, DO, pH, NO_3-N, Fe, Mn, TDS, TP, EC, salinity, and hardness were selected.

A time-series method was applied to analyze the water samples and measure the quality parameters. A time series method is an efficient and straightforward method for analyzing the past behavior of a time-series variable to predict its future behavior when independent causal variables influencing the time-series variable are unknown or cannot be determined. This technique as applied to the creation of the WQI requires uncomplicated data sets and less time for computation. In addition, other factors influencing water quality (e.g., changes in land use and population growth) were assumed to indirectly reflect the changing patterns of the 13 water quality parameters. The modified WQI was used to evaluate the raw water quality at MWA water supply production facilities. In addition, the WQI indicates the tendency for the deterioration of raw water over time, informing MWA awareness and planning for future, periodical inspections of the raw water at their inspection points.

The purpose of this study was to determine the raw water quality before the MWA analysis starting at raw water receival locations, for raw water from the Chao Phraya River into the Eastern Water Supply Canal at Samlae, Pathum Thani Province. The raw water is pumped and transmitted to the Bangkhen Water Treatment Plant (WTP), Thon Buri WTP, and the Samsen WTP. If the MWA can ascertain the water quality of raw water, in the form of the WQI, before the pumping station, it would be able to better manage the water supply production system.

2. STUDY AREA AND WATER QUALITY MEASURING STATION

Raw water used in the MWA water treatment process is taken from the Chao Phraya River at the Samlae Pumping Station which is located at Samlae in Pathum Thani Province, about 18 km north of the Bangkhen Water Treatment Plant. The Samlae Pumping Station is the first point that takes water from the Chao Phraya River into the MWA's east canal and is located 41 kilometers away from Bangkok, and 90 kilometers away from the Gulf of Thailand (Figure 1). The capacity of the station is 3.8 million cubic meters per day.

The data used to analyze the WQI values were obtained from 9 PCD water quality sampling stations upstream from the Samlae raw water pumping station to the Chao Phraya dam in Chainat province, as depicted in Figure 2 with location details in Table 1. In ordinary conditions, the PCD measures the quality of raw water four times per year.

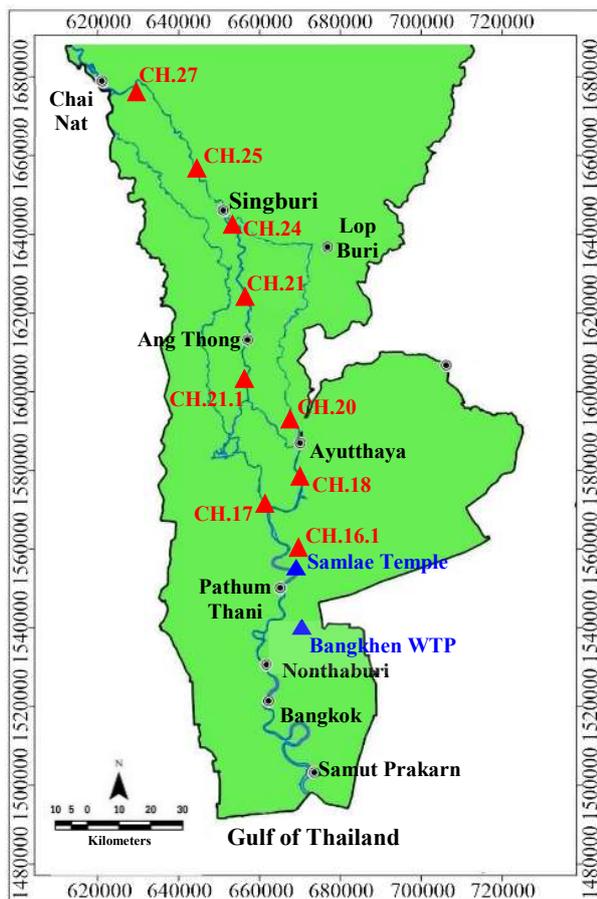**Figure 1** Samlae raw water pumping station, Pathum Thani

Figure 2 Location of the 9 PCD water quality sampling stations

The PCD in the Bureau of Water Quality Management monitored the water quality at 18 stations along the Chao Phraya River twice in the rainy season and twice in the dry season, and 28 water quality parameters were measured. In 2016, the PCD evaluated that the Chao Phraya River receives approximately 4.8 million cubic meters of wastewater per day from communities (10%), industrial plants (35%), aquaculture farms (10%), and swine farms (5%). As a result, the Biochemical Oxygen Demand Loading (BOD-loading) is approximately 369,421 kg/day. In the dry season, when there is no

rainwater drainage of fertilizers and pesticides from the fields into the Chao Phraya River, the river receives the most waste from the community, industry, and agriculture, with the burden of the community waste the most. The potential discharging sources are residential areas, temples, government offices, schools, hospitals, and restaurants Pilailar and Urantinon (2019). These discharges cause high BOD with low DO, mainly as the river flows through Bangkok which is the most densely populated area along the Chao Praya River. Although The Chao Phraya River flowing through the Samlae raw water pumping station has water quality in the tier 3 criterion, it tends to deteriorate under the influence of rising tides allowing less freshwater to flow in the lower parts of the river.

Table 1 Location of the PCD's water quality sampling stations

Station	Distance from Samlae Pumping Station (KM.)	Water quality sampling station	District	Province
CH16.1	0	Samlae raw water pumping station	Mueang	Pathum Thani
CH17	5	Sam Khok Police Station	Sam Khok	Pathum Thani
CH18	28	Bang Pa-In Paper Factory	Bang Pa-In	Ayutthaya
CH20	47	Pom Phet	Mueang	Ayutthaya
CH21.1	69	Sa Kaeo temple	Pa Mok	Ang Thong
CH21	87	Ang Thong City Hall	Mueang	Ang Thong
CH24	131	The bridge crossing the Chao Phraya River	Mueang	Sing Buri
CH25	148	In-Buri Bridge	In-buri	Sing Buri
CH27	181	Chao Phraya Dam	Sapphaya	Chai Nat

The recorded data from the Samlae raw water quality sampling station on the Samlae canal in Pathum Thani Province also shows the trend of BOD and DO, as shown in Figure 3. Those data show that the water river tends not to meet the criterion of raw water for water supply production.
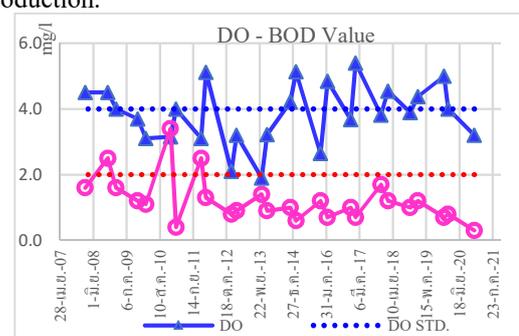

Figure 3 BOD and DO at Samlae's MWA Water Intake

3. METHODOLOGY

3.1 Data collection

The water quality data at nine stations along the Chao Phraya River, gathered by the PCD from 2008 to 2020, are shown in Table 1. These data include the water quality measures at the Samlae pumping station of the MWA which adopted these data based on the water quality standards guidelines that were recommended by several officials at the MWA, PCD, and WHO. The parameters related to the water supply products, previously discussed, were selected to consider the WQI for raw water.

3.2 Development of the WQI

The first step was the selection of the parameters that influence the water quality of raw water in the water supply production. This initial step started with examining data availability; the screening procedures and the multivariate statistical methods that were applied Prakirake et al., (2009). The rating curves of the selected parameter for each were then developed. The objective of this step was to transform the water quality parameter observations into a common scale (0 to 100).

In establishing the rating curves, expert judgment and statistical methods were used to develop the rating curves and define key points in agreement with the permissible limits from water quality standards. The actual parameter transformation was achieved through categorical scaling and linear interpolation. The weights corresponding to each parameter, ranging from 0 and 1, were assigned according to their importance to the overall water quality. To assign weights to the parameters, participatory-based approaches that have been widely used in the Delphi method and the Analytical Hierarchy Process were adopted, and are admittedly subjective.

The fourth and final step was to select the weighted sub-index values' aggregation method and the formula WQI value. The standard formula for the WQI aggregation method, Horton (1965) is shown in Eq. (1)

$$WQI = \sum_{i=1}^{n} Wi \times Qi \qquad (1)$$

where   Qi   is the water quality parameter s' index i
       Wi   is the associated weighing factor for each parameter
       n   is the number of parameters

This equation gives the result of a single value of WQI, which ranges from 0 to 100. It classifies the water body's quality into five different categories.

3.3 Procedure of WQI

As stated in the introduction section, there are four steps for the development of WQI. Figure 4 summarizes the methods used for each step in the WQI modification for raw water specific to MWA.
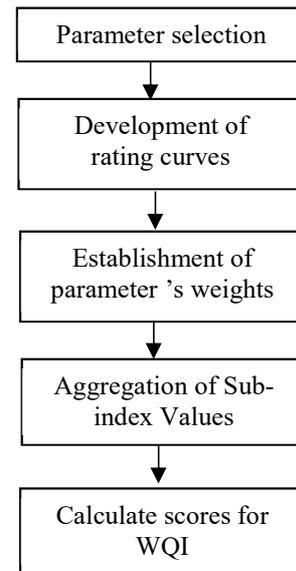

Figure 4 Procedure of Establishing WQI for Raw Water

3.4 Parameter selection

In this lateral study, the raw water quality data from the PCD was collected 4 times per year, twice in the rainy season, June to September, and twice in the dry season, October to February. These data can be classified for their significance in the parameters in the rainy season and dry season. Therefore, the weighting criteria scores of significant parameters will be different, water quality parameters and given scores (ranging from the poorest, 0, to the best, 100) to each range of values of their selected parameters. Other information influencing water quality (e.g., land use change, water consumption, and human activities along the riversides) were also aggregated from the water quality experts' opinions. The data obtained from the water quality experts and Brown et al., (1970) were used to create the rating curves for the 13 water quality parameters previously described The thirteen rating curves were tested for a year using the values of the associated water quality parameters observed at the nine sampling stations and with the recorded data from 2008 to 2020, and their suitability was adjusted for better determination of the water conditions in the Chao Phraya River.

In general, expert judgment can be incorporated into the selection of parameters through three approaches; individual interviews, interactive groups, and the Delphi method Meyer and Booker (1990). Of the three approaches, the Delphi method is the one that has been widely used for the selection of parameters Prakirake et al., (2009). The purpose of this method is to mine the view or opinions of experts without having the experts congregate at an agreed time and define the Delphi method Linstone and Turoff (1976).

3.5 Development of rating curves

The observed values of each water quality parameter were converted into sub-index scores for the parameter. To assign the sub-index values, the water quality parameters are presented as a two-dimensional (X-Y coordinate) plot where the sampling data in the X-Axis and Q-value within the Y-Axis, ranging on the scale of 0 to 100, where 0 and 100 represented the poorest and the highest of the water quality.

The construction of WQI was developing the rating curves for each of the selected parameters. The rating curves were extended to reach the complete concentration distribution ranges of the water quality parameters. Additionally, the rating curve for pH was horizontally displaced, so the maximum suitable pH, (value = 7) sub-index value was assigned to 100% of the Q-value in the Y-Axis.

Based on these criteria, the sub-index transformation curves for each selected parameter were assigned. Then, rating curve equations (sub-index functions) for each parameter were numerically formulated by curves fitting and approximation of function method using Microsoft Excel®. To aid the rating equation, scores for selected parameters were then approximated Uddin et al., (2021).

The techniques for creating similar sub-index transformation curves for water quality Prakirake et al., (2009).

3.6 Establishment of parameter's weights

The third step for constructing the WQI was to establish the weights of the 13 selected parameters to measure their relative importance to the final index value. Weights were assigned only to the desired parameters. A biplot was used to interpret these components and each of the selected water quality parameters' vectors. The length of the vector from the origin to the coordinates reflects the variance of that variable. To determine the weights of each selected parameter, the range scale was determined and normalized by the sum of all the range scales. Thus, the sum of all normalized values.

In this study, the weights of each selected parameter were determined through seasonal change, dry season, and rainy season. A Temporary Weight (TW) was developed by dividing the Significant Rating (SR) of each parameter. The weighting Scale (WS) for each parameter was defined as the ratio of the TP weight to the summation of the TW weights. The WS was obtained by approximating the ratio of the TW for each variable to the summation of the TW values Prakirake et al., (2009) TW and WS of the thirteen parameters according to Eq. (2) and Eq. (3)

$$TW = \frac{Highest\ of\ Significant\ Rating}{Each\ Significant\ Rating} \quad (2)$$

$$WS = \frac{Eac\ Temporary\ Weight}{\sum Temporary\ Weight} \quad (3)$$

In addition, the thirteen parameters were selected for the development of WS through seasonal consideration: dry season and rainy season.

The importance values and roles, for the dry season, were conductivity, salinity, and DO, and BOD with WS of 0.10 considered the most important variable for determining water supply quality while hardness and TDS with WS of 0.08 were the second most important, as shown in Table 2.

In the rainy season, TDS and turbidity with WS of 0.10 were considered the most important variables for determining water supply quality while color, hardness, Fe, NO₃-N, BOD, DO, and TP with WS of 0.08 were of lesser importance, as shown in Table 3.

Table 2 Selected Parameters Weights in Dry Season

Parameter	Unit	Weighting Scale		
		SR	TW	WS
pH	-	1.40	0.70	0.07
Color	Pt-Co	1.40	0.70	0.07
Hardness	mg/l	1.60	0.80	0.08
TDS	mg/l	1.60	0.80	0.08
Fe	mg/l	1.20	0.60	0.06
Mn	mg/l	1.20	0.60	0.06
NO₃-N	mg/l	1.20	0.60	0.06
BOD	mg/l	2.00	1.00	0.10
DO	mg/l	2.00	1.00	0.10
Total PO₄-P	mg/l	1.40	0.70	0.07
Conductivity	(µS)	2.00	1.00	0.10
Salinity	ppt	2.00	1.00	0.10
Turbidity	NTU	1.40	0.70	0.07
		∑	10.20	1.00

Table 3 Selected Parameters Weights in Rainy Season

Parameter	Unit	Weighing Scale		
		SR	TW	WS
pH	-	1.00	0.50	0.05
Color	Pt-Co	1.60	0.80	0.08
Hardness	mg/l	1.60	0.80	0.08
TDS	mg/l	2.00	1.00	0.10
Fe	mg/l	1.60	0.80	0.08
Mn	mg/l	1.40	0.70	0.07
NO₃-N	mg/l	1.60	0.80	0.08
BOD	mg/l	1.60	0.80	0.08
DO	mg/l	1.60	0.80	0.08
Total PO₄-P	mg/l	1.60	0.80	0.08
Conductivity	(µS)	1.40	0.70	0.07
Salinity	ppt	1.40	0.70	0.07
Turbidity	NTU	2.00	1.00	0.10
		∑	10.20	1.00

3.7 Classification for categories of water quality

The WQI scores for all stations on the river were used to categorize the overall water quality into classes following Notification No. 8: Surface water quality standard, the 1992 Thailand Enhancement and Conservation of National Environmental Quality Act. The five surface water quality classes with specific characteristics are shown in Table 4.

Table 4 Categories of Water Quality and WQI Scores

Class	Descriptor Categories	Score	Descriptive
1	Very good	85 - 100	Extra clean freshwater resources. Consumption requires only ordinary processing for pathogenic destruction.
2	Good	80 - 85	Very clean freshwater resources. Consumption requires an ordinary water treatment process which minor purification required before use.
3	Average	65 - 80	Medium clean freshwater resources. Consumption requires a conventional water treatment process before use.
4	Poor	40 - 65	Fairly clean freshwater resources. Consumption requires a specific or advanced water treatment process before use.
5	Very poor	< 40	Unacceptable

Considering the relationship between surface water quality standard categories and the range scales of the selected water quality parameter, the maximum-average-minimum of WS scores for the water collected was used as the baseline classification. The actual water quality is in the range of very poor to very good. Ranges of scale were adjusted using the average value of WS obtained from the MWA's Samlae raw-water intake, and the water quality data from the PCD. For the rating curve for each water quality classification, the scores of the very good class for each WQI were taken as the maximum data point of the "good" class. The maximum data point of the "good" class was 83, which may be approximated as the baseline of the very good class score (score over 85). Therefore, range scales for the good and average for the individual class were designated, respectively, as the average scores to upper limit scores and average scores of the "average" to average values of the "good" class. Therefore, the range of the "poor" class spanned between average scores of the "average" and "very poor" class is shown in Table 5.

Table 5 relationship of selected parameters and range scale

Parameter	Unit	Water quality Classification for water treatment plant				
		Very good	Good	Average	Poor	Very poor
pH	-	7	6.8 – 7.2	6.5 - 8.5	< 5.0 > 9.0	< 2.0 >12.0
Color	Pt-Co	≤ 10	20	100	200	> 200
Hardness	mg/l as CaCo$_3$	≤ 20	50	100	200	400
TDS	mg/l	≤ 200	1,000	1,200	1,500	> 1,500
Fe	mg/l	≤ 1	0.5	50	70	> 70
Mn	mg/l	≤0.5	1	5	10	> 10
NO$_3$-N	mg/l	≤ 2.5	5	10	15	> 15
BOD	mg/l	≤ 1	1.5	2.00	2.5	5
DO	mg/l	≥ 6.6	5.32	4.00	2.28	< 2.0
Total PO$_4$-P	mg/l	≤ 0.04	0.15	0.3	0.7	> 0.7
Conductivity	(μS)	50	200	500	1,000	1,500
Salinity	ppt	0.05	0.15	0.25	1.50	2.00
Turbidity	NTU	< 8	20	75	144	> 144

4. RESULT AND DISCUSSION

The relationship between the observed values from nine water quality sampling stations of the PCD and water quality sampling data from the MWA Samlae raw-water pumping station were converted into rating curves for each water quality parameter. These rating curves were modified from the relationship of the selected parameters and the range scales and categories of the surface water quality standards, presented as two-dimensional (X-Y coordinates), as illustrated in Figures 5-1, 5-2 up to 5-13. The associated equations for converting to a score were numerically formulated by curve fitting and the approximation of function method using Microsoft Excel®. With the aid of the rating equation, scores for each selected parameter were then approximated, as shown in Table 6.

The Q-value for all water quality parameters in this study evaluated the water quality, where input the water quality sampling data in the X-Axis and the Q-value within the Y-Axis, ranging on the scale of 0 to 100, where 0 and 100 represented the poorest and the highest of the water quality.

The values of the thirteen parameters obtained in the analysis of the average of the water quality sampling data are shown in Table 5. The highest are TDS, hardness, and BOD. It can be seen that water quality at that time is still good or very good. However, there is local pollution upstream, especially in the social and industrial expansion areas.

For long-term analysis, surface water quality data obtained between 2005 and 2020 from the natural water resources intended for water supply, from the Chao Phraya River at the upper MWA Samlae Raw-water Intake, Amphur Muang Pathum Thani province, were analyzed and evaluated using the WQI. The water qualities of the Chao Phraya River in general were average.

Table 6 Equations of sub-index rating curve for water quality
parameters' index

Parameter	Equation
pH	$Qi = -21.429x^2 + 300x - 967.14$
Color	$Qi = 0.0006x^2 - 0.4706x + 92.424$
Hardness	$Qi = 0.0008x^2 - 0.5581x + 102.6$
TDS	$Qi = -9E-06x^2 - 0.0358x + 105.09$
Fe	$Qi = -0.0015x^2 - 0.9562x + 98.91$
Mn	$Qi = 0.2362x^2 - 10.786x + 100.73$
NO_3-N	$Qi = 0.1099x^2 - 8.4305x + 117.88$
BOD	$Qi = -0.1056x^2 - 10.732x + 102.66$
DO	$Qi = 0.1233x^2 + 16.848x - 15.933$
Total PO_4-P	$Qi = 255x^2 - 309.27x + 94.929$
Conductivity	$Qi = 3E-05x^2 - 0.1098x + 100.64$
Salinity	$Qi = 14.341x^2 - 69.274x + 86.549$
Turbidity	$Qi = -4E-06x^2 - 0.6169x + 96.173$

Where x is the water quality from the raw water quality data

In this study, the WQI was evaluated against that reported by the MWA at the Samlae raw-water intake. The results suggested that the WQI value, calculated from the selected parameters from the water sampling station during the dry season, (1st October to 30th April) is appropriate for the water supply. The WQI score was 78.37, and the range of the WQI in categories in class 3. In the rainy season, (1st May to 31st August) the calculated WQI score was 74.63, and was in the same range of WQI as in the dry season, as illustrated in Tables 7 and T8. The water quality was average to good because the upstream of Chao Phraya River was less contaminated by pollution point sources throughout the river, including communities, industrial plants, aquaculture, and various animal farms than downstream.

WQI Calculation and parameters analysis should be considered the peak or critical event of parameter values. For example, in February 2021, drought and the incursion of saltwater in river basins caused a crisis in Thailand, resulting in more discharge from upstream reservoirs to manage such problems. Upstream water from the Chao Phraya River basin was not enough to push seawater intrusion back at the MWA Samlae Raw-water Intake.

Thus, seawater contamination in raw water leads to increasing salinity of the water supply (MWA raw water standard salinity value ≤ 0.25 g/l), and water treatment plants cannot remove saltiness from the raw water. In this situation, water quality is not up to potable water standards which may affect consumers and cause damage to the country's industrial sector in the future.

The WQI score was applied in evaluating the trend of water quality. Results are illustrated in Figure 6. It can be seen that in the dry season, the WQI value tends to be better than the WQI values in the rainy season. The rainy season WQI may be influenced by soil erosion, chemicals, and industrial and community effluents that flow into the raw water sources. If considering the trend of annual average discharge value. It can be seen that the trend of 2018-2020 was a continuous decrease in runoff volume. This will affect the WQI values for both the dry and rainy seasons during 2018-2020. The WQI values in

the dry season were 78.89, 81.79, 82.58, 81.76, 81.14, 78.70, and 67.94, the WQI values in the rainy season were 68.75, 74.07, 78.73, 79.59, 79.12, 77.20, 76.52 and 68.50 (forecast value), respectively which seems to indicate that the WQI value is relative to the decrease of annual discharge.

If the forecasting value is true, the water quality became poor water, fairly clean freshwater resources for consumption purposes require a conventional water treatment process or advanced water treatment process before being used since the water quality was under average level.

Typically, the climate variability effect or drought encountered, when evaluating water quality, yields obscure water quality. However, the index proposed shows the effect of climate variability on water quality prediction, in particular the raw water quality of the water treatment process.

5. CONCLUSIONS

The established WQI can be used instead of the traditional water quality evaluation since the developed WQI requires only 13 selected parameters rather than the usual 42 parameters generally used. This illustrates that the WQI provides a more convenient way to understand water quality than a long list of numerical values for a group of parameters. This enables the public and non-scientific communities to share and understand the data monitored. The WQI can assist those in charge of the water resource to make more efficient use of the Decision Support System (DSS) of the authorities to improve water quality to sustain water supply usage.

Overall, it may be inferred that the WQI may serve as a tool for describing water quality in terms of the specific water usage for the water supply. The WQI may also be used as a tool for measuring water quality trends in the water source. The water supply index developed in this study and the minimum operators may be used as an indicator reflecting the presence of pollutants in the river or water resource.

As a result, the MWA should be aware of the need to periodically inspect and sample the raw water, and to develop a tool and methods to solve the problem more efficiently and thereby reduce the impact of water pollution more successfully than before. Appropriate tools and strategies, such as those developed in this study, can solve the various problems, particularly saltwater intrusion, more effectively.
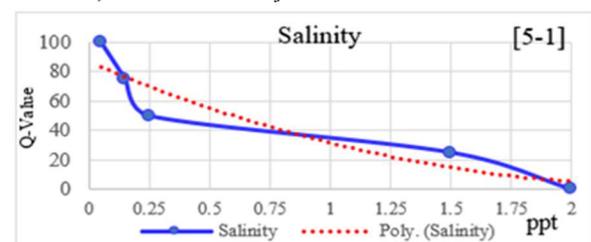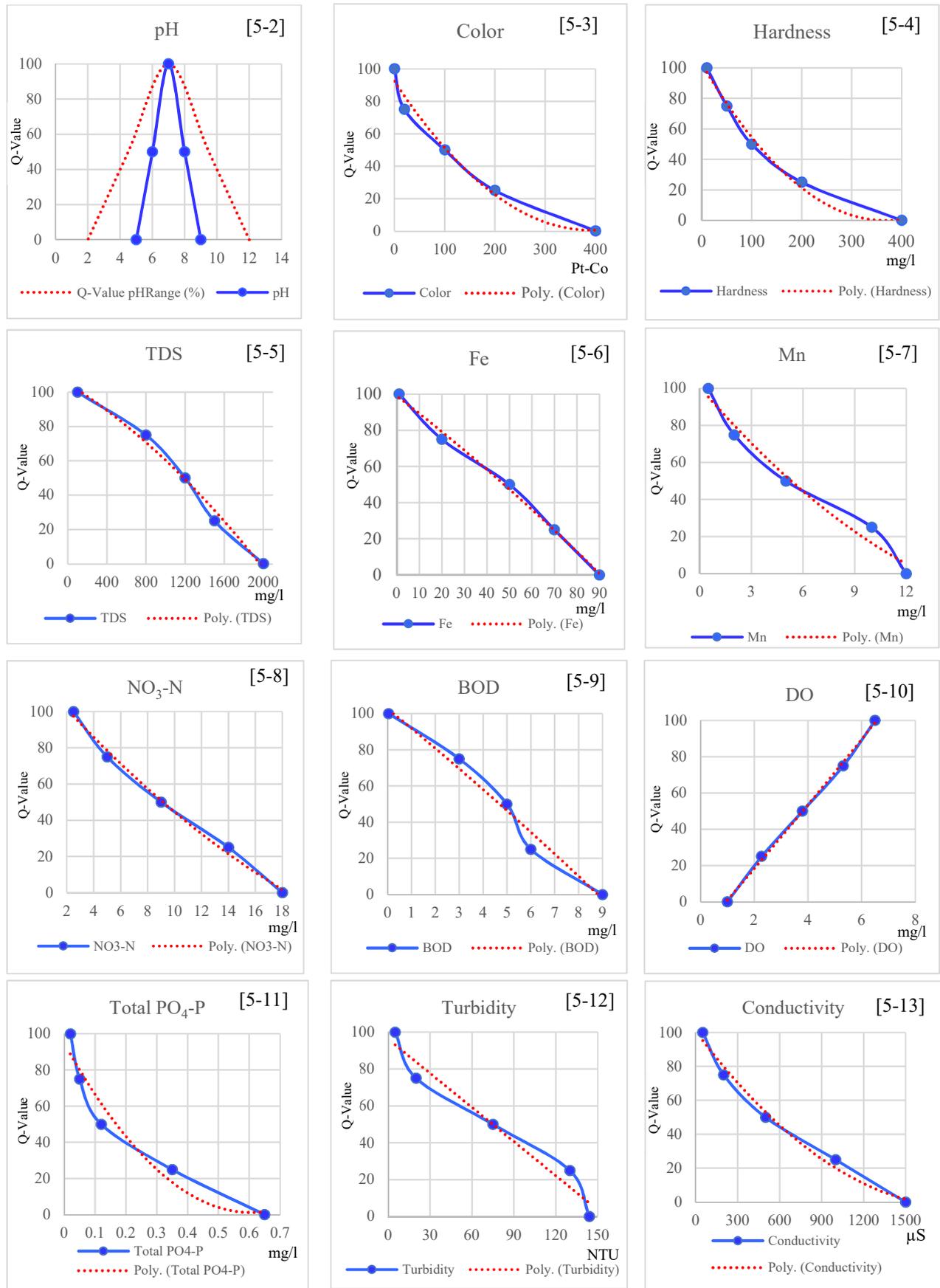

Figure [5-1] rating curves of parameters

Figure [5-2] – [5-13] Rating curves of water quality parameters

Table 7 the average WQI value in the dry season (1st September – 30th April, 2010 - 2021)

Parameter	Unit	Weighting Scale			Sampling data	Q-Value	WS*Q-Value
		SR	TW	WS			
pH	-	1.40	0.70	0.07	7.35	80.270	5.51
Color	Pt-Co	1.40	0.70	0.07	1.00	91.954	6.31
Hardness	mg/l	1.60	0.80	0.08	101.98	54.006	4.24
TDS	mg/l	1.60	0.80	0.08	278.61	94.417	7.41
Fe	mg/l	1.20	0.60	0.06	0.89	98.056	5.77
Mn	mg/l	1.20	0.60	0.06	0.09	99.804	5.87
NO$_3$-N	mg/l	1.20	0.60	0.06	1.30	100.000	5.88
BOD	mg/l	2.00	1.00	0.10	1.85	82.444	8.08
DO	mg/l	2.00	1.00	0.10	3.86	50.917	4.99
Total PO$_4$-P	mg/l	1.40	0.70	0.07	0.10	65.421	4.49
Conductivity	(μS)	2.00	1.00	0.10	280.96	72.159	7.07
Salinity	ppt	2.00	1.00	0.10	0.20	73.268	7.18
Turbidity	NTU	1.40	0.70	0.07	24.50	81.054	5.56
		∑	10.20	1.00		WQI =	78.37

Table 8 the average WQI value in the rainy season (1st May – 31st August, 2010 - 2021)

Parameter	Unit	Weighting Scale			Sampling data	Q-Value	WS*Q-Value
		SR	TW	WS			
pH	-	1.00	0.50	0.05	7.53	76.816	3.77
Color	Pt-Co	1.60	0.80	0.08	11.00	87.320	6.85
Hardness	mg/l	1.60	0.80	0.08	40.00	81.556	6.40
TDS	mg/l	2.00	1.00	0.10	1113.00	54.096	5.30
Fe	mg/l	1.60	0.80	0.08	0.47	98.460	7.72
Mn	mg/l	1.40	0.70	0.07	0.02	100.514	6.90
NO$_3$-N	mg/l	1.60	0.80	0.08	2.26	100.000	7.84
BOD	mg/l	1.60	0.80	0.08	2.00	80.774	6.34
DO	mg/l	1.60	0.80	0.08	4.10	55.216	4.33
Total PO$_4$-P	mg/l	1.60	0.80	0.08	0.01	92.777	7.28
Conductivity	(μS)	1.40	0.70	0.07	2232.00	5.021	0.34
Salinity	ppt	1.40	0.70	0.07	0.40	61.134	4.20
Turbidity	NTU	2.00	1.00	0.10	34.00	75.194	7.37
		∑	10.20	1.00		WQI =	74.63
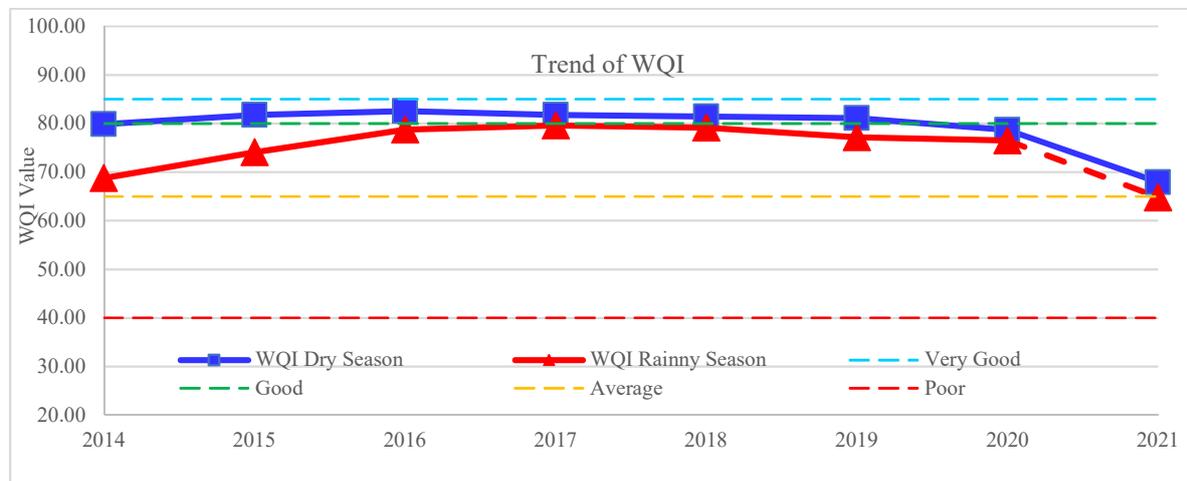
Figure 6 Trend in water quality of WQI scores for the dry season and rainy season between 2014 – 2021

6. ACKNOWLEDGMENTS

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