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# APPLICATION OF WATER QUALITY INDEX FOR THE SURFACE WATER QUALITY ASSESSMENT OF DAM VOI LAKE, YEN BAI PROVINCE

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**Abstract**

*In this study, the guidelines approved in Decision No. 1460/QD-TCMT dated November 12nd, 2019 of the Vietnam Environment Administration were applied to assess Dam Voi lake's surface water quality belonging to Tran Yen district, Yen Bai province. To perform this process, the authors monitored and analyzed 13 indicators of surface water samples in April and May in 2021 at various three positions. The data shows that all 13 indicators of all samples are in the allowed limitation of B1 column in the National technical regulation on surface water quality QCVN 08-MT:2015/ BTNMT, including pH, $NO_3^-$, $Cl^-$, Cd, Pb, total iron (Fe), TSS, COD, $BOD_5$, $NH_4^+$, $NO_2^-$, $PO_4^{3-}$ and coliform. It means the water of examined regions only consists of irrigation and other equivalent purposes. Moreover, calculated WQI values indicate that the water quality of Dam Voi lake was almost excellent, except for the end area of the lake (NM3 site). The WQI values show that the water quality of the NM3 site was at a moderate level, which is caused by the increase of Pb content. Importantly, these results could be a database for future researches in the monitoring process of water quality changes at Dam Voi lake.*

**Keywords**: Surface water; Water quality index; WQI; Water quality.

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## 1. Introduction

Water has been an essential natural resource for humankind, animals and plants, which can bring to either healthy or diseased life depending on the quality of water resources [1, 2]. Since water quality is associated with public health and sustainable development, the quality assessment of water sources, especially for surface water, has become an important task [3]. Water quality monitoring plays a significant role in collecting data required to identify existing problems and forecast coming issues for water sources. According to standards, the parameter analysis of water samples can help managers determine contaminated factors. However, these parameters may be pretty tricky to visually clarify in a comprehensible and comparative manner [4, 5]. Water Quality Index (WQI) is a valuable tool developed to evaluate analytical data and descript water quality [3, 6, 7]. In Vietnam, WQI values have been widely used to assess

the water quality of water resources such as rivers, lakes and coastal areas [8 - 10]. These studies indicated that WQI values help managers to assess the overall quality of water sources and then conduct appropriate policies for environmental management.

Dam Voi lake, located in Dam Voi park, is an urban landscape at Co Phuc town, Tran Yen district, Yen Bai Province [11]. The park was officially opened in March 2012 and various social activities such as exercises, fishing, kid playground. The lake possesses an essential function in the daily life activities of citizens and the development of the area. Nonetheless, the surface water quality of Dam Voi lake has recently been threatened by the risk of pollution, which is caused by the consciousness, living habits and daily activities of citizens such as garbage throwing, wastewater discharging into the lake. Therefore, monitoring and assessing of the lake's water quality must be frequently and scientifically performed. Since Dam Voi lake's water quality has not been officially published so far, the results obtained from these works could be an efficient database for the management and protection of the water source of Dam Voi lake.

## 2. Methods

Herein, we report the monitoring processes of surface water samples collected at various sites of Dam Voi lake. The samples were taken in two periods, one month apart, for comparison purposes. Analytical data show that the parameters of the water samples do not alter much between two periods, implying the stability of the water source. Significantly, these parameters do not exceed their limit values in national technical regulation on surface water quality QCVN 08-MT:2015/BTNMT (B1 Column) [12]. On the other hand, WQIs were calculated from the analytical data to evaluate the water quality based on the technical guidance of the Vietnam Environment Administration (Decision 1460/QD-TCMT, dated November 12$^{nd}$, 2019) [13]. The WQIs confirm that the water quality of both two periods is at an excellent level for NM1 and NM2 sites and a moderate level for the NM3 site.

### *2.1. Study area*

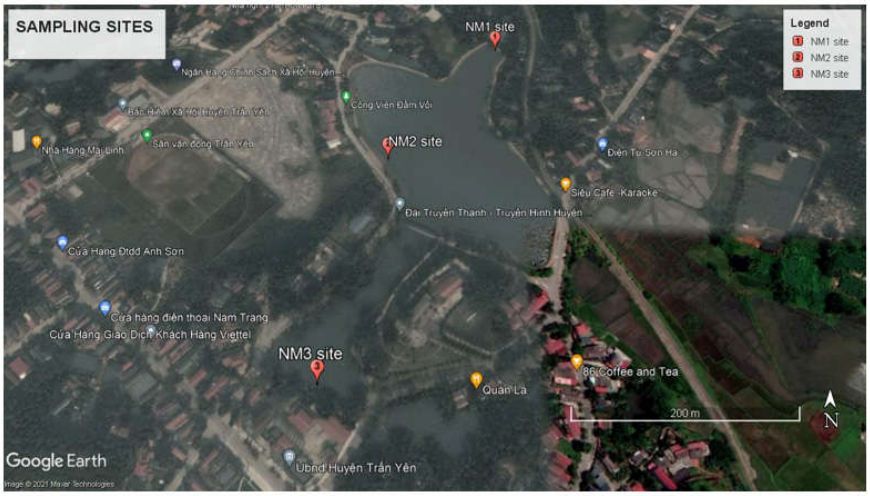


***Figure 1: Water sampling sites in Dam Voi lake marked by red placemark icons along with sample codes (the picture taken from Google Maps)***

Dam Voi lake has a surface area of about 40,000 $m^2$ and a reservoir capacity of 80,000 $m^3$ (Fig. 1). The lake's water is provided from Hoa Cuong spring, which is mainly used fr irrigation purposes. In addition, the lake is currently receiving domestic wastewater from households around the lake. In order to assess water quality, the water samples taken from the lake were collected in April and May 2021, in which climate type is north's summer season (Tab. 1).

The sampling sites are the same in the two periods described at Table 2. Three sampling sites are the beginning, middle and ending points of Dam Voi lake, denoted as NM1, NM2, NM3, respectively.

***Table 1. Time and weather characteristics of sampling periods***

| Period | Time | Climate | Temperature |
|---|---|---|---|
| 1 | 10 - 11 am, April 3rd 2021 | Cloudy | 22 °C |
| 2 | 4 - 5 pm, May 1st 2021 | Light sunshine | 28 °C |

***Table 2. Coordinates and features of sampling sites***

| Sample | Coordinates | | Features of the sites |
|---|---|---|---|
| | **Latitude** | **Longitude** | |
| NM1 | 21°45'30.7"N | 104°49'53.6"E | More waste<br>Near a sewer |
| NM2 | 21°45'25.7"N | 104°49'49.5"E | Least waste<br>Troubled water |
| NM3 | 21°45'17.8"N | 104°49'47.6"E | Yellow-green water<br>The end of the lake |

### *2.2. Water sampling and analysis*

Water samples were collected and preserved according to the guidance of Vietnam standards TCVN 5994:1995 (ISO 5667 - 4:1987) and TCVN 6663 - 3:2008 (ISO 5667 - 3:2003).

Thirteen water quality parameters of samples were observed, including pH, total suspended solids (TSS) (mg/L), COD (mg/L), $BOD_5$ (mg/L), $NO_2^-$ (mg/L), $NO_3^-$ (mg/L), $NH_4^+$ (mg/L), $PO_4^{3-}$ (mg/L), $Cl^-$ (mg/L), coliforms (MPN/100 mL), total Fe (mg/L), Cd (mg/L) and Pb (mg/L). These parameters were analyzed at analytical laboratory for environment, dioxin and toxins belonging to Northern Center for Environmental monitoring, Vietnam Environment Administration (VILAS 545). The analytical method of each parameter is reported in Table 3.

***Table 3. Methods for the analysis of water quality parameters***

| Parameter | Method number | Analytical method |
|---|---|---|
| pH | TCVN 6492:2011 | pH meter |
| $BOD_5$ | TCVN 6001 - 1:2008 | Inoculation and dilution methods |
| COD | TCVN 6419 - 1999 | Titration method |
| TSS | TCVN 6625 - 2000 | Weighing and drying method |
| $NO_3^-$ | TCVN 6494 - 1:2011 | Ion chromatography |
| $NH_4^+$ | SMEWW - 4500 - $NH_3$.F:2012 | Continuous flow method on CFA |
| $NO_2^-$ | TCVN 6494 - 1:2011 | Ion chromatography |
| $PO_4^{3-}$ | TCVN 6202:2008 | Photometric method |

| | | |
|---|---|---|
| $Cl^-$ | TCVN 6494 - 1:2011 | Ion chromatography |
| Cd | EPA Method 200.8 | Inductive Plasma Mass Spectrometer |
| Pb | EPA Method 200.8 | Inductive Plasma Mass Spectrometer |
| Fe | EPA Method 200.8 | Inductive Plasma Mass Spectrometer |
| Coliform | TCVN 6187 - 2:1996 | Multi-tube method |

### *2.3. Data Analysis*

The water quality parameters were compared with QCVN 08-MT: 2015/BTNMT the National technical regulation on surface water quality [12]. The water quality index (WQI) was calculated with the guidance of the Vietnam Environment Administration (2019) [13] and presented as a geographic map. The distribution of colors on the map was proposed based on the calculated WQI values (Fig. 2).

The parameters used to calculate a WQI value in the guidance of the Vietnam Environment Administration (2019) are divided into five groups, including the pH parameter group, the pesticide parameter group (Aldrin, BHC, Dieldrin, DDTs (p, p' - DDT, p, p' - DDD, p, p' - DDE), Heptachlor and Heptachlorepoxide), the heavy metal parameter group (As, Cd, Pb, $Cr^{6+}$, Cu, Zn and Hg), the organic and nutritional parameter group (DO, $BOD_5$, COD, TOC, $NH_4^+$, $NO_3^-$, $NO_2$ and $PO_4^{3-}$) and the microbiological parameter group (Coliform and E.coli). The calculation of WQI needs at least 03/05 parameter groups and at least three parameters belong to organic and nutritional parameters.

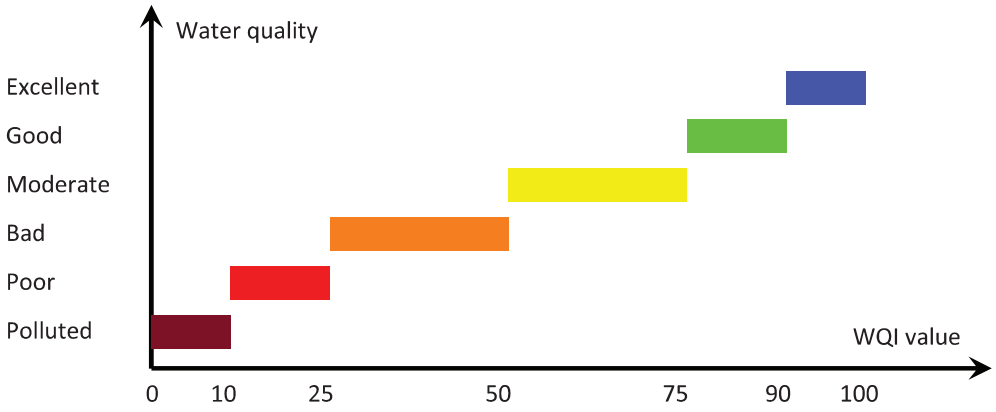


***Figure 2: The representation of WQI values on the map by colors***

WQI values were calculated by Eq. 1 [13]:

$$WQI = \frac{WQI_I}{100} \times \frac{\left(\prod_{i=1}^{m} WQI_{III}\right)^{1/m}}{100} \times \left[\frac{1}{k}\sum_{i=1}^{k} WQI_{IV} \times \frac{1}{h}\sum_{i=1}^{h} WQI_V\right]^{1/2} \quad \text{(Eq. 1)}$$

Where, $WQI_I$, $WQI_{III}$, $WQI_{IV}$, $WQI_V$ are WQI values for the parameter groups of pH, heavy metals, organic and nutritional compounds and microbiology, respectively.

In this study, WQI values for the parameters ($WQI_{SI}$) of Cd, Pb, $BOD_5$, COD, $NH_4^+$, $NO_3$, $NO_2^-$, $PO_4^{3-}$ and coliform were calculated by the Eq. 2 [13]:

$$WQI_{SI} = \frac{q_i - q_{i+1}}{BP_{i+1} - BP_i}(BP_{i+1} - C_p) + q_{i+1} \quad \text{(Eq. 2)}$$

Where, $BP_i$ and $BP_{i+1}$ are the lower and upper bound concentration of the monitoring parameters at i and i+1 levels, respectively, regulated by the Vietnam Environment Administration; $q_i$ and $q_{i+1}$ are WQI values for $BP_i$ and $BP_{i+1}$, respectively; $C_p$ is the actual value of parameters.

WQI value for the parameters of pH was determined as follows [13]:

- pH < 5.5 or pH > 9: $WQI_{pH} = 10$

- 5.5 < pH < 6: $WQI_{pH}$ was calculated by the Eq. 3

$$WQI_{SI} = \frac{q_{i+1} - q_i}{BP_{i+1} - BP_i}(C_p - BP_i) + q_i \quad \text{(Eq. 3)}$$

- 6 ≤ pH ≤ 8.5: $WQI_{pH} = 100$

- 8.5 < pH < 9: $WQI_{pH}$ was calculated by the Eq. 2

## 3. Results and discussion

### *3.1. Surface water quality parameters of Dam Voi lake*

***Table 4. pH values, heavy metal content and microbiological parameter of water samples***

| Parameter | Period 1 | | | Period 2 | | | Limit value [12] | |
|---|---|---|---|---|---|---|---|---|
| | NM1 | NM2 | NM3 | NM1 | NM2 | NM3 | A1 | B1 |
| pH | 6.6 | 7.2 | 6.7 | 6.7 | 7.1 | 6.8 | 6 – 8.5 | 5.5 – 9 |
| Cd (mg/L) | 0.0001 | 0.0001 | 0.0006 | 0.0002 | 0.0002 | 0.0009 | 0.005 | 0.01 |
| Pb (mg/L) | 0.001 | 0.006 | ***0.047*** | 0.001 | 0.005 | ***0.048*** | 0.02 | 0.05 |
| Total Fe (mg/L) | 0.24 | 0.21 | 0.19 | 0.22 | 0.16 | 0.14 | 0.5 | 1.5 |
| Coliform (MPN/100 mL) | 240 | 150 | 240 | 460 | 240 | 210 | 2500 | 7500 |

Table 4 shows the pH values of water samples collected from Dam Voi lake in two periods. The pH values ranged from 6.6 to 7.2, within the allowable range of QCVN 08-MT:2015/BTNMT (B1 Column) [12].

The analytical results of heavy metals show that the contents of Cd and Fe in the samples are below their limit values in the A1 column of the National technical regulation. On the other hand, only the content of Pb in the samples of the NM3 site is higher than its allowable limit in the A1 column. It may probably be caused by the accumulation of waste at the end of the lake. The increase of Pb content at the NM3 site may be due to the abrasion of the domestic wastewater pipelines. When wastewater flows through the pipelines, it could elute some metals and other materials composing the pipelines. However, these values are still lower than the allowable limit of Pb in the B1 column. It implies that the water of Dam Voi lake may be consistent with irrigation and domestic water supply.

The density of coliforms in the monitoring samples ranged from 150 to 460 MPN/100 mL. According to the limit value of coliform in QCVN 08-MT:2015/BTNMT, A1 column (2500 MPN/100 mL), coliform density in the study area does not exceed the permitted limit. The coliform density of the NM1 sample (Period 2) was much higher than other samples. Domestic waste discharges may cause this in sampling time.

The analytical results of organic and nutritional parameters are summarised in Table 5. The data exhibits that COD, $PO_4^{3-}$ and TSS parameters exceed their allowed limits at the A1 column but are still lower than at the B1 column (QCVN 08-MT:2015/BTNMT). The

results indicate that the water source of the lake may accommodate irrigation and transportation purposes. Moreover, almost all parameters of the NM1 site have the highest values compared with that of other sites. This can be explained by the presence of domestic sewages near to NM1 site. Moreover, the variation of data at the same sites but two different periods could come from the sampling time difference. For example, the samples of period two were collected from 4 - 5 pm, at which the living activities of households were raised. Therefore, the content of some parameters at the NM1 site in Period 2 was higher than that in Period 1.

***Table 5. Organic and nutritional parameters of water samples***

| Parameter | Period 1 | | | Period 2 | | | Limit value [12] | |
|---|---|---|---|---|---|---|---|---|
| | NM1 | NM2 | NM3 | NM1 | NM2 | NM3 | A1 | B1 |
| $BOD_5$ (mg/L) | ***9.3*** | ***8.9*** | ***9.0*** | ***11.6*** | ***8.0*** | ***7.8*** | 4 | 15 |
| COD (mg/L) | ***15.1*** | ***13.8*** | ***16.0*** | ***19.2*** | ***12.3*** | ***12.0*** | 10 | 30 |
| $NH_4^+$ (mgN/L) | 0.22 | 0.3 | 0.19 | 0.16 | 0.19 | 0.14 | 0.3 | 0.9 |
| $NO_3^-$ (mgN/L) | 0.44 | 0.42 | 0.37 | 0.454 | 0.35 | 0.31 | 2 | 10 |
| $NO_2^-$ (mgN/L) | 0.044 | 0.045 | 0.035 | 0.042 | 0.036 | 0.028 | 0.05 | 0.05 |
| $PO_4^{3-}$ (mgP/L) | ***0.23*** | ***0.16*** | ***0.17*** | ***0.14*** | ***0.18*** | ***0.24*** | 0.1 | 0.3 |
| $Cl^-$ (mg/L) | 6.04 | 3.24 | 3.26 | 4.75 | 3.28 | 3.10 | 250 | 350 |
| TSS (mg/L) | ***36.2*** | ***30.6*** | ***36.3*** | ***40.6*** | ***37.2*** | ***35.6*** | 20 | 50 |

### *3.2. WQI values of Dam Voi kake*

***Table 6. WQI values of the surface water of Dam Voi kake***

| Parameter | Period 1 | | | Period 2 | | |
|---|---|---|---|---|---|---|
| | NM1 | NM2 | NM3 | NM1 | NM2 | NM3 |
| $WQI_{pH}$ | 100 | 100 | 100 | 100 | 100 | 100 |
| $WQI_{Cd}$ | 100 | 100 | 100 | 100 | 100 | 100 |
| $WQI_{Pb}$ | 100 | 100 | 32.5 | 100 | 100 | 30.0 |
| $WQI_{BOD_5}$ | 65.8 | 66.9 | 66.7 | 59.4 | 69.4 | 70.0 |
| $WQI_{COD}$ | 74.8 | 81.0 | 73.3 | 68.0 | 88.5 | 90.0 |
| $WQI_{NH_4^+}$ | 100 | 100 | 100 | 100 | 100 | 100 |
| $WQI_{NO_3^-}$ | 100 | 100 | 100 | 100 | 100 | 100 |
| $WQI_{NO_2^-}$ | 100 | 100 | 100 | 100 | 100 | 100 |
| $WQI_{PO_4^{3-}}$ | 67.5 | 85.0 | 82.5 | 90.0 | 80.0 | 65.0 |
| $WQI_{coliform}$ | 100 | 100 | 100 | 100 | 100 | 100 |
| WQI | 92.0 | 94.2 | 53.2 | 92.9 | 94.7 | 51.2 |

WQI values of sampling sites were calculated based on the parameters of pH, Cd, Pb, $BOD_5$, COD, $NH_4^+$, $NO_3^-$, $NO_2^-$, $PO_4^{3-}$ and coliform according to the guidance of the Vietnam Environment Administration (Decision 1460/QD-TCMT, dated November 12, 2019) (Tab. 6). The calculated results of WQI values

express that the water quality of sampling sites was affected by the parameters of $BOD_5$, COD and $PO_4^{3-}$. Furthermore, the WQI values of the NM3 site show the significant effect of Pb content. The WQI values of NM1 and NM2 sites (92 - 95) also indicate that the water quality of monitoring sites reaches to an excellent level (blue color). In comparison, the NM3 site is marked with yellow color identifying as a moderate level (Fig. 3). WQI calculation results show that the difference between sampling locations and two sampling times is not too different. At the NM3 site, water quality was worse than NM1 and NM2, resulting from the content increase of Pb, $BOD_5$ and $PO_4^{3-}$ indicators at NM3. To improve WQI values and the water quality of the lake, managers should reinforce monitoring and indoctrination to reduce the sewage discharge of households living around the lake and citizens visiting the park.

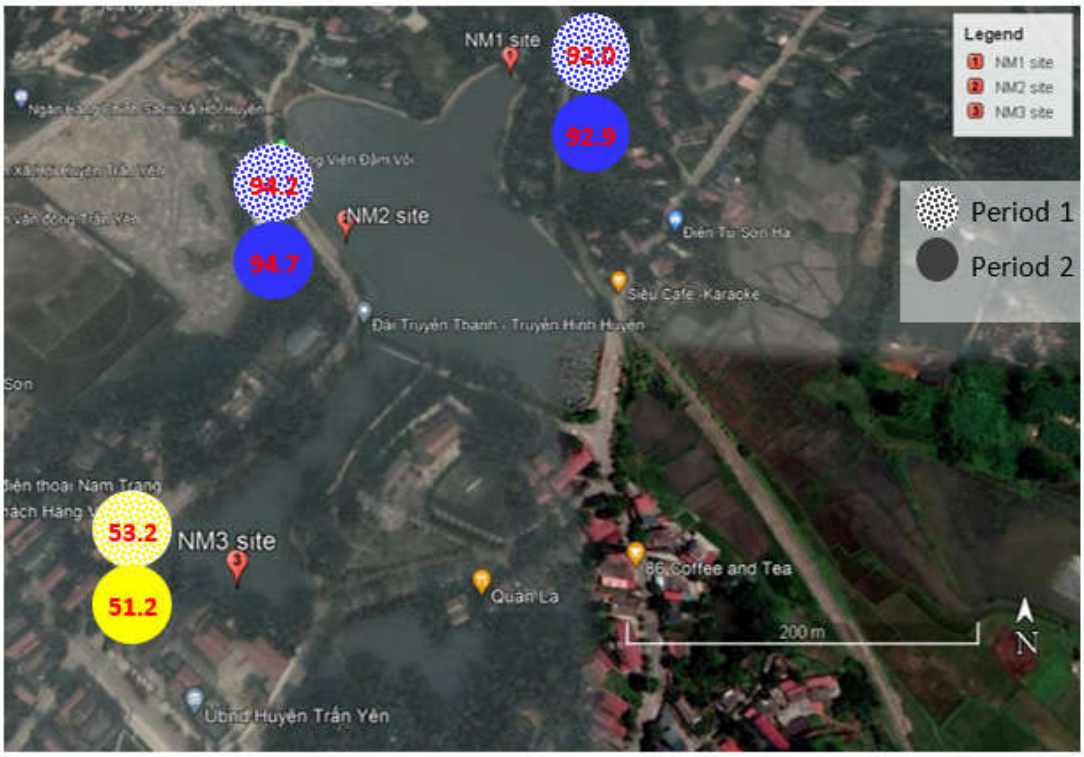


***Figure 3: Water quality map of Dam Voi lake in April (Period 1) and May (Period 2) 2021***

## 4. Conclusions

The surface water quality of Dam Voi lake in 2021 has been monitored by the parameters of pH, $NO_3^-$, $Cl^-$, Cd, Pb, total iron (Fe), TSS, COD, $BOD_5$, $NH_4^+$, $NO_2^-$, $PO_4^{3-}$ and coliform. The results show that all indicators were below their limits regulated in column B1 of QCVN 08-MT: 2015/BTNMT. Analytical results show that the difference of parameters between sampling locations and two sampling times is not too different. However, some parameters such as TSS, COD, $BOD_5$, $PO_4^{3-}$ and Pb (NM3 site) exceeded the allowed values of column A1. Therefore, Dam Voi lake's water source should only be used for irrigation purposes but not for domestic water supply.

Moreover, this data was expressed by the WQI values, which could enable us to clearly clarify Dam Voi lake's water quality. The WQI values clearly showed

the water quality at NM1 and NM2 sites in both periods was at excellent levels (blue color), whereas that at NM3 site was at a moderate level. Notably, the results obtained from our work should be a database for future research or the management and preservation of water resources.

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