

Temporal and spatial water quality assessment of Thay Cai – An Ha canal system, Vietnam

A D Pham^{1,2} and T H Y Nguyen¹

¹Faculty of Environment and Labour Safety, Ton Duc Thang University, Ho Chi Minh City, Vietnam

E-mail: phamanhduc@tdt.edu.vn

Abstract. The Thay Cai–An Ha Canal located in the districts of Cu Chi, Hoc Mon, Binh Chanh – Ho Chi Minh City, apart of Long An Province with an area of approximately 50 km². This system was important of Ho Chi Minh City, providing water for agriculture, drainage and even navigation in local area. Data from 16 sites from the Thay Cai–An Ha Canal in the districts of Cu Chi, Hoc Mon, Binh Chanh – Ho Chi Minh City, and a part of Long An Province were collected in April 2013, 2014, 2015 and 2016 analyzed for pH, total suspended solid (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD₅), chemical oxygen demand (COD), amoni (NH₄⁺), phosphate (PO₄³⁻), and coliform. Then all data were used for calculation and mapping. The ArcGIS 9.3 software, Inverse Distance Weighting (IDW) interpolation, and hydrologic variables in April 2013, 2014, 2015 and 2016 were applied to build the maps of water quality for the Thay Cai–An Ha Canal. The results classified water quality of the Thay Cai–An Ha Canal System at 3 classes, as described by The Vietnam Environmental Protection Agency, usage for water use for irrigation (1); water use for navigation (2); and, heavy pollution (3). Additionally, the results of environmental variables at 16 sites in the Thay Cai–An Ha Canal System sampled April 2013, 2014, 2015 and 2016 showed that the water quality at almost sites were so polluted with TSS values at 73 – 156 mg/L, DO from 0.1 to 2.9 mg/L; NH₄⁺ from 1.07 to 7.89 mgO₂/L; PO₄³⁻ from 0.05 – 2.65 mg/L, and coliform from 2.3x10³ to 5.2x10⁵ MPN/100mL. Last but not least, two main prior approaches of water quality improvement for the Thay Cai – An Ha were suggested. It could not be used for water supply and protection of aquatic communities.

1. Introduction

The Thay Cai–An Ha Canal located in the districts of Cu Chi, Hoc Mon, Binh Chanh – Ho Chi Minh City (HCMC), apart of Long An Province with an area of approximately 50 km². It is length over 48 kilometers (figure 1) [1]. This system was important of HCMC, providing water for agriculture, drainage and even navigation in local area. The Thay Cai–An Ha Canal which flowed nearly the Tan Phu Trung Industrial Park is heavily polluted with untreated wastewater discharged from factories in this industrial park. The HCMC Department of Agriculture and Rural Development has recently raised concerns about the rising levels of pollution in the Thay Cai–An Ha canal, which supplies water for cultivation to over 9,000 hectares in Hoc Mon and Binh Chanh districts. Additionally, polluted water was also flowing in from another areas, bringing in wastewater from enterprises in Long An Province, and Hoc Mon and Cu Chi Districts – HCMC. They instead emitted hazardous wastewater into Thay Cai–An Ha Canal [2]. The monitoring report 2014 by HCMC Environmental Protection Agency showed that the serious degradation of quality surface water of the canal system. TSS, COD, BOD₅,



and Coliform parameters were found as exceed the levels of the National Technical Regulation for Surface Water Quality of levels A1 and A2, while the DO concentrations was lower than minimum allowed level) [1].

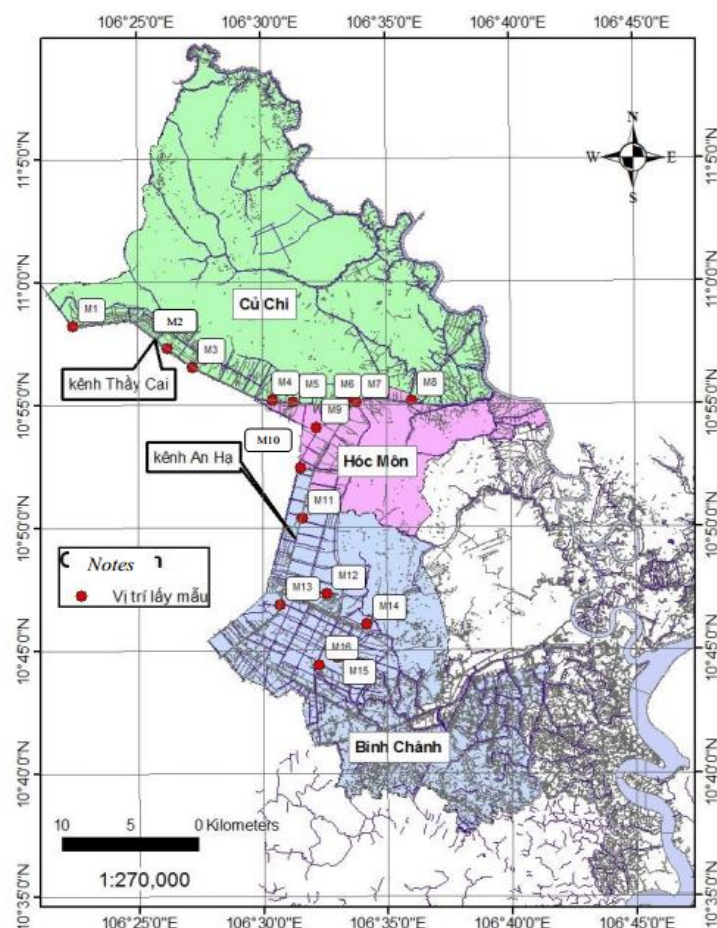


Figure 1. Map of sampling sites.

In order to contribute the water resources management and improve the water quality monitoring for the Thay Cai–An Ha Canal, the parameters of pH, TSS, DO, BOD₅, COD, NH₄⁺, PO₄³⁻, and coliform was described. Moreover, the ArcGIS 9.3 software, Inverse Distance Weighting (IDW) interpolation, and hydrologic variables in April 2013, 2014, 2015 and 2016 were applied to build the maps of water quality assessment for the Thay Cai–An Ha Canal. The objectives of this research were to: (1) Evaluate the properties of water quality for the Thay Cai–An Ha Canal; (2) Apply the GIS system for building the maps of water quality for the Thay Cai–An Ha Canal; and (3) Suggest the approaches for water quality improvement.

2. Methods

2.1. Study sites and sample collection

Based on the characteristics of natural conditions and socio-economic development, 16 sampling sites for the Thay Cai – An Ha Canal were suggested and representative for a sampling program (figure 1). The samples were collected according to methods presented in the Operational Guide (3rd Ed.), UN Environment Programme [3]. The water samples of various physiochemical parameters were taken in

April from 2013 to 2016. Locations at each site were sampled in the middle of the canals with depth layer at 30-40 cm from water surface. Water samples were collected using 2 liter plastic containers and preserved at 2°C [3].

2.2. Physical and chemical analysis

The water samples were analyzed for aquatic environmental parameters (pH, total suspended solid – TSS, dissolve oxygen – DO, biological oxygen demand – BOD₅, chemical oxygen demand – COD, ammonia – NH₄⁺, phosphate – PO₄³⁻, and coliform) using standard methods recommended APHA-AWWA-WEF, 1998 [4].

2.3. Calculation of water quality index (WQI)

The WQI for building the forecast maps was calculated from Vietnam Environment Administration [5]. The WQI was based on 6 parameters pH, TSS, DO, BOD₅, COD, NH₄⁺, PO₄³⁻, and coliform. The classification of water quality for usage purposes was presented in table 1.

Table 1. Classification of water quality for usage purposes [5].

No.	Ranking WQI	Usage Purposes	Color Indicators
1	91 – 100	Good quality for water supply	Blue
2	76 – 90	Use for water supply required appropriate treatment	Green
3	51 – 75	Water use for irrigation	Yellow
4	26 – 50	Water use for navigation	Orange
5	0 – 25	Heavy pollution	Red

Notes: Level of heavy pollution means that the water quality can not meet any level of the National Technical Regulation.

2.4. Mapping buiding procedures

IDW interpolation function was used the measured values surrounding the prediction location in belows [6]:

$$\lambda_i = \frac{\sum_{j=1}^G \lambda_j / D_{ij}^p}{\sum_{j=1}^G 1 / D_{ij}}$$

Where λ_i was the property at location i ; λ_j was the property at location j ; D_{ij} was the distance from i to j ; G was the number of sampled locations; and p was the inverse-distance weighting power.

Weights were proportional to the inverse distance raised to the power value p [7]. The characteristics of the interpolated surface can also be controlled by limiting the input points used in the calculation of each output cell. Limiting the number of input points considered can improve processing speeds [8,9].

3. Results and discussion

3.1. Characteristics of water quality

The results of water quality analysis for the Thay Cai – An Ha Canal were presented table 2. The analyzed results in many sites exceeded the National Technical Regulation for Surface Water Quality of levels A1 (good quality for water supply) and A2 (good quality for protection of aquatic communities), especially values of TSS, DO, NH₄⁺, and coliform [10].

Generally, the results at 16 sites sampled from 2013 to 2016 showed that the water quality in the Thay Cai-An Ha Canal were polluted highly. It could not be used for water supply and protection of

aquatic communities. In this canal system, there were few species of benthic macroinvertebrates these indicated for the medium or heavy pollution as *Potamilla* sp., *Bispira polymorpha* (Polychaete); *Limnodrilus hoffmesteri*, *Branchiura sowerbyi* (Oligochaeta); *Chironomus* sp., *Endochironomus* sp., *Polypedilum* sp. (Diptera), these were dominant [11,12].

Table 2. Water quality parameters for the Thay Cai – An Ha Canal in April, 2013 – 2016.

Sites	pH	TSS (mg/L)	DO (mg/L)	BOD ₅ (mg/L)	COD (mg/L)	NH ₄ ⁺ (mg/L)	PO ₃ - (mg/L)	Coliform (MPN/100mL)
M1	6.5–6.8	39–72	1.6–4.9	5.4–7.1	8.2–13.5	3.16–6.78	0.03–2.65	930–5200
M2	6.3–7.1	57–88	2.2–2.9	2.9–5.8	7.3–13.6	6.41–7.89	0.05–0.46	2300–43000
M3	6.3–6.8	45–86	1.4–2.5	3.1–7.3	6.2–14.3	3.19–5.38	0.02–0.27	2300–43000
M4	6.3–6.6	69–102	1.4–2.8	3.1–5.8	6.9–12.2	0.58–2.12	0.07–0.32	9300–43000
M5	6.7–7.2	64–77	0.1–2.6	5.4–15.5	10.1–55.7	0.97–2.98	0.04–1.05	4300–43000
M6	6.5–6.9	75–84	0.7–2.2	3.9–7.1	6.4–13.0	0.99–3.58	0.04–0.30	4300–230000
M7	6.9–7.5	124–131	0.3–2.2	4.8–6.7	9.1–15.5	4.07–5.81	0.17–0.44	43000–230000
M8	7.0–7.4	86–124	0.8–2.7	4.0–6.7	10.4–16.5	1.68–5.14	0.12–0.48	52000–430000
M9	7.1–7.5	79–103	0.7–1.1	4.6–9.9	10.0–18.6	3.21–5.18	0.13–0.62	230000–520000
M10	7.0–7.5	95–111	0.7–1.8	4.5–7.7	8.7–17.1	2.16–3.46	0.09–0.42	93000–230000
M11	6.8–7.4	77–121	1.6–2.1	3.7–9.0	8.6–14.3	1.22–2.39	0.10–0.40	4300–11000
M12	7.1–7.5	102–156	1.1–1.6	3.7–8.0	9.5–17.4	3.27–5.57	0.11–0.36	23000–52000
M13	7.0–7.4	73–113	1.4–2.0	3.5–7.4	9.3–13.4	1.07–2.18	0.12–0.34	4300–11000
M14	6.9–7.4	80–113	1.3–2.0	3.8–8.2	9.1–13.6	1.19–3.93	0.11–0.37	4300–11000
M15	7.0–7.4	90–106	0.7–1.5	4.1–8.4	9.6–14.3	1.98–4.35	0.12–0.38	5200–23000
M16	6.8–7.3	92–139	1.0–1.5	4.2–7.3	9.7–15.2	1.87–3.87	0.14–0.41	5200–23000

3.2. Water quality index (WQI)

The values of WQI calculation at 16 sites for the Thay Cai-An Ha Canal were presented in table 3. The results of water quality in the Thay Cai-An Ha were classified at 3 classes, as described by The Vietnam Environmental Protection Agency, water use for irrigation (1); water use for navigation (2); and, heavy pollution (3). The results showed that the water quality of Thay Cai-An Ha Canal have not been improved in recent years [11,12]. The water quality in the Thay Cai-An Ha Canal had a tendency to worsen.

Table 3. Classification of water quality based on WQI values for the Thay Cai – An Ha Canal in April, 2013 – 2016.

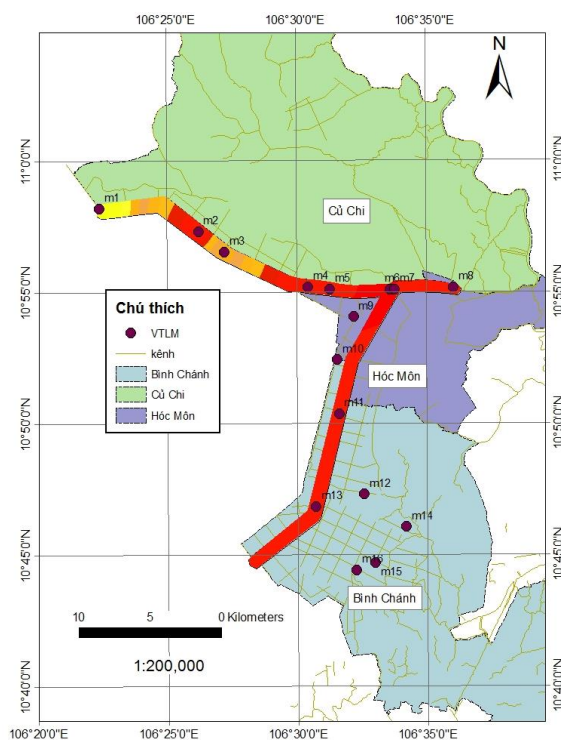
No.	Sites	2013	Usage Purposes	2014	Usage Purposes	2015	Usage Purposes	2016	Usage Purposes
1	M1	52	Water use for irrigation	43	Water use for irrigation	38	Water use for navigation	22	Heavy pollution
2	M2	6	Heavy pollution	14	Heavy pollution	19	Heavy pollution	18	Heavy pollution
3	M3	26	Water use for navigation	27	Water use for irrigation	18	Heavy pollution	16	Heavy pollution
4	M4	14	Heavy pollution	8	Heavy pollution	9	Heavy pollution	9	Heavy pollution
5	M5	12	Heavy pollution	12	Heavy pollution	11	Heavy pollution	12	Heavy pollution
6	M6	6	Heavy pollution	8	Heavy pollution	8	Heavy pollution	9	Heavy pollution
7	M7	14	Heavy	15	Heavy	14	Heavy	14	Heavy

8	M8	14	pollution Heavy	15	pollution Heavy	14	pollution Heavy	13	pollution Heavy
9	M9	20	pollution Heavy	15	pollution Heavy	13	pollution Heavy	14	pollution Heavy
10	M10	16	pollution Heavy	16	pollution Heavy	15	pollution Heavy	15	pollution Heavy
11	M11	15	pollution Heavy	16	pollution Heavy	15	pollution Heavy	15	pollution Heavy
12	M12	12	pollution Heavy	12	pollution Heavy	13	pollution Heavy	12	pollution Heavy
13	M13	12	pollution Heavy	10	pollution Heavy	11	pollution Heavy	12	pollution Heavy
14	M14	12	pollution Heavy	11	pollution Heavy	10	pollution Heavy	11	pollution Heavy
15	M15	9	pollution Heavy	7	pollution Heavy	8	pollution Heavy	7	pollution Heavy
16	M16	8	pollution Heavy	10	pollution Heavy	10	pollution Heavy	9	pollution Heavy

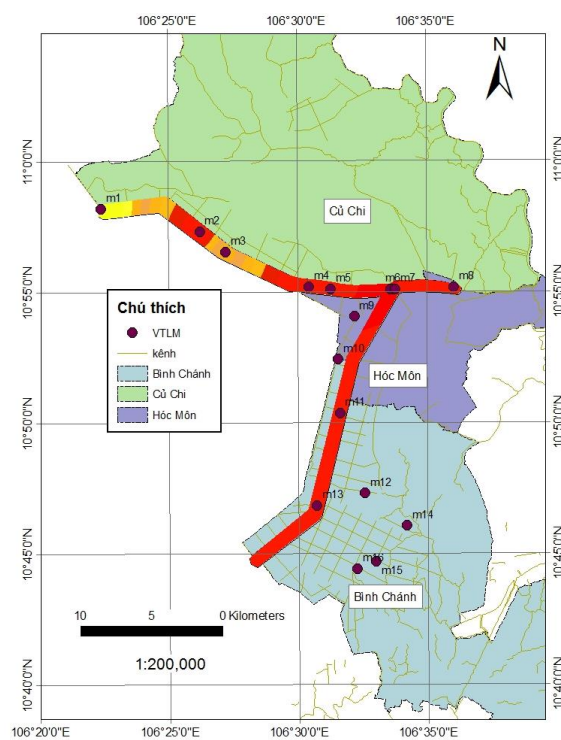
3.3. Mapping of water quality

The maps of the water quality zonation for the Thay Cai-An Ha Canal in April 2013, 2014, 2015 and 2016 were showed in figure 2. These results were suitable with the characteristics of socio-economic development as industrial activities and urban development in the Thay Cai-An Ha Canal basin.

The main cause of water pollution in this canal system was the discharge of untreated wastewater directly into surrounding canals by various industrial enterprises. In particular, the Thay Cai canal was being polluted by the Tan Phu Trung Industrial Zone, Duc Hoa 1 Industrial Zone, Duc Hoa 2



(a)



(b)

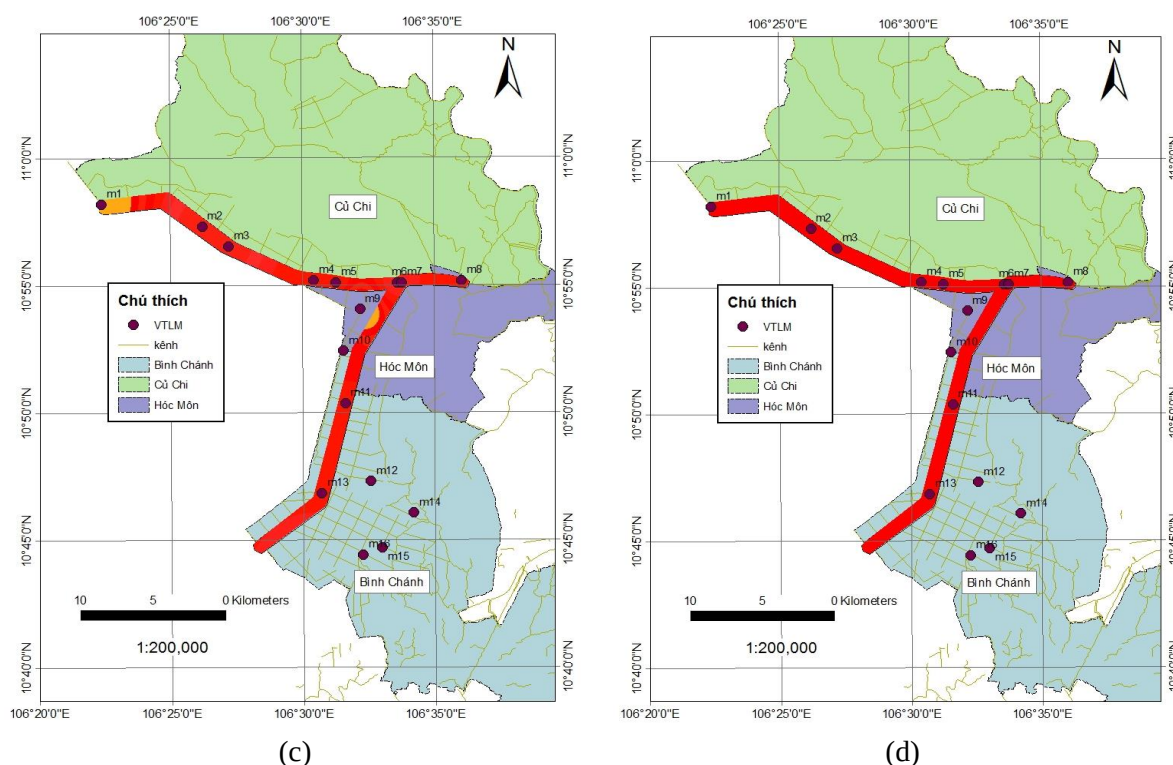


Figure 2. Maps of water quality in the Thay Cai-An Ha Canal. April, 2013 (a), 2014 (b), 2015 (c), and 2016 (d).

Industrial Zone, Trang Bang Industrial Zone and the Linh Trung III Export Processing Zone. The canals were also being polluted by large amounts of waste from Cu Chi District – HCMC and Duc Hoa – Long An [13].

Especially, the species of benthic macroinvertebrates these indicated for the heavy pollution was disappeared [11,12].

3.4. Approaches for water quality improvement

Table 4. Mud dredging and hyacinth cleaning techniques.

No.	Items	Length of canal	Amount of work	Cost
1	Mud dredging techniques	30,000 m	140,000 m ³ of mud dredging	1,297,000 USD
2	Hyacinth cleaning techniques	12,000 m	12,000 m length of hyacinth cleaning	258,000 USD

The Department of Natural Resources and Management suggested the release of wastewater into Thay Cai – An Ha Canal needed be inspected, especially in pollution hot spots. The production workshops would be required to build a wastewater treatment facility and operate according to regulations [14,15]. Enterprises with wastewater treatment facilities that released more than 1,000 m³ of wastewater a day must establish the automatic wastewater monitoring system. Additionally, enterprises that continue to pollute will have to relocate or cease operations [14]. In 2017, the municipal authority has continued to carry out several projects on canal pollution. The projects included building wastewater treatment factories, dredging canals and collecting rubbish [15].

Generally, there were many solutions offered to control the water quality the Thay Cai – An Ha Canal. There were two priority solutions that need to be implemented immediately (table 4).

4. Conclusion

This result indicated the water quality at the Thay Cai-An Canal in April 2013, 2014, 2015 and 2016. The water quality at almost sites were so polluted with TSS values at 73 – 156 mg/L, DO from 0.1 to 2.9 mgO₂/L; NH₄⁺ from 1.07 to 7.89 mg/L; PO₄³⁻ from 0.05 – 2.65 mg/L, and coliform from 2.3x10³ to 5.2x10⁵ MPN/100mL. It could not be used for water supply and protection of aquatic communities. Additionally, the WQI based on the parameters pH, TSS, DO, BOD₅, COD, NH₄⁺, PO₄³⁻, and coliform in combination with GIS system were calculated. The water quality of the Thay Cai-An Ha was classied at 3 classes, as described by The Vietnam Environmental Protection Agency, usage for water use for irrigation (1); water use for navigation (2); and, heavy pollution (3). It could not be used for water supply and protection of aquatic communities. The main cause of water pollution in this canal system was the discharge of untreated wastewater directly into surrounding canals by various industrial enterprises. Moreover, two main prior approaches of water quality improvement for the Thay Cai – An Ha were suggested. This research could be a scientific reference to suggest effective approaches for water quality improvement in the Thay Cai-An Ha Canal system.

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