STUDY ON CARRYING CAPACITY OF THE TRUONG GIANG RIVER, QUANG NAM PROVINCE

Mai Trong Hoang[1,2] , Tran Van Thuy[2] , Nguyen Dang Giap[3] , Nguyen Le Tuan[4]
[1]Viet Nam Institute of Meteorology, Hydrology and Climate Change
[2]Faculty of Environmental Sciences, VNU University of Science
[3]Key Laboratory of River and Coastal Engineering, Viet Nam Academic for Water Resources
[4]Viet Nam Institute of Seas and Island, Viet Nam Administration of Seas anh Islands

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Abstract: *The paper presents the study on environmental carrying capacity of Truong Giang River, Quang Nam province for BOD and NH_4^+, in the dry season (from April to June) and rainy season (from October to December) in 2017. The study used MIKE 21 model to simulate water quality and assess the carrying capacity of Truong Giang River by three different scenarios. Results show that, for the Scenario 1, all 4 river-sections of Truong Giang River were no longer able to withstand the load of BOD and NH_4^+. In particular, the section I had the best carrying capacity, followed by the section IV and section III, and the lowest one was the section II. For the Scenario 2, all 4 river-sections were still capable of receiving pollutants, except for BOD in section II and III in the rainy season. For the Scenario 3 with a warning meaning, in order to meet the minimum requirements of water quality to ensure the functions of the water source, it is necessary to limit the amount of pollution load discharged into the river by 1.94 times of BOD and 2.45 times of NH_4^+ compared to its of the year 2017. This result lays the foundation for further research on solutions to increase self-purification ability and improve water quality in the Truong Giang River.*

Keywords: *Carrying capacity, pollutants, Truong Giang River, Quang Nam province.*

1. Introduction

Truong Giang River is located in Quang Nam province, with a length of 67km, merging with the downstream in the north of Thu Bon River to flow into the sea through the Dai estuary, and merging with the downstream of Tam Ky River to flow into the sea through the Lo and An Hoa estuary. The Truong Giang River is of paramount importance to local people, providing water for aquaculture, water transportation and flood drainage for the coastal plain. This is also the habitat of many valuable aquatic and marine species.

Recently, people have arbitrarily encroached on the riverbed for aquaculture and built constructions on the river without planning. This has caused sedimentation of the riverbed and narrowed the flow. In particular, socio-economic development activities, such as aquaculture, industry and livestock farming in the region have been generating sources of polluting waste, pressurizes on water environment of the Truong Giang River.

Despite facing with the situation mentioned above, there has been no research on the pollutant carrying capacity of the Truong Giang River. Therefore, we conducted this study to assess the potential of major contaminants discharged into the Truong Giang River according to scenarios. The results serve as a basis for the orientation of planning, rational exploitation and use of the Truong Giang River for socio-economic development in association with environmental protection.

Corresponding author: Mai Trong Hoang
E-mail: tronghoangmhh@gmail.com

2. Methods and data

2.1. Object and scale of the study

- Object of the study: Pollution carrying capacity for parameters of BOD and NH_4^+ for Truong Giang River, Quang Nam province.

- Research scale:

+ Space range: The entire Truong Giang River has a length of 67km, starting from the junction of An Lac at Duy Xuyen district to An Hoa at Nui Thanh districts. Based on the characteristics of the Truong Giang River (the location of the river inlet, the distributary on the river; the purpose of using the water source in each river section), refer to the provisions of the Circular No.76/2017/TT-BTNMT in December 29, 2017 and the Decision No.154/QD-TCMT of February 15, 2019 relating to carying capacity of the water source [1, 6], the study has divided Truong Giang River into 4 sections to evaluate the pollution carrying capacity including: Section I (Duy Xuyen - Thang Binh), section II (Thang Binh section), section III (Thang Binh - Tam Ky - Nui Thanh) and section IV (Truong Giang lagoon) (Figure 1).

Figure 1. Location of Truong Giang River in Quang Nam Province (Zoom out from 1:100000-scale map)

+ Time range: This paper presents the results in the base year (2017) in the driest months in the dry season (from June to June) and rainy months (from October to December).

2.2. Research methods

As the Truong Giang River has a special morphology, influenced by tides at 3 estuaries (Dai estuary in the North, Lo and An Hoa estuaries in the South), there is a complex hydrodynamic regime that requires a set of strong modeling toolsfor simulation. The MIKE model, set up by the Danish Hydraulic Institute (DHI) integrates many powerful tools including strong modules such as rainfall-runoff (MIKE NAM) and one-dimension flow (MIKE 11) [8], two-dimension flow (MIKE 21) [9], advection-diffusion (MIKE AD) [10] and water quality (MIKE Ecolab) [11], etc. The MIKE is a specialized technical software, bringing high applicability to simulate discharge, flow, water quality in estuaries, rivers, canals and other water bodies. Therefore, this study used two MIKE model tools, MIKE 11 and MIKE 21, to study the pollution carrying capacity of the Truong Giang River. The MIKE 11 is used to simulate the flow of water through river crossings

and provide input data for MIKE 21. MIKE 21 is responsible for simulating the flow field, distributing pollutant components and pollutant carrying capacity of the Truong Giang River according to different scenarios.

The study has implemented to simulate water quality of Truong Giang River with scenarios in 2017 in dry season (from April to June) and rainy season (from October to December). From there, the linear regression correlation function between the pollutant discharge load and the pollution parameter value at the representative point was determined, for each river section, through running the model with the change of input load with decreasing rate, 75%, 50% and 25%. From this linear regression function, it is possible to determine the carrying capacity of each section of the Truong Giang River with different scenarios according to the limitations of values of pollution parameters in QCVN (QCVN 08-MT: 2015/BTNMT) (Figure 2) [6].

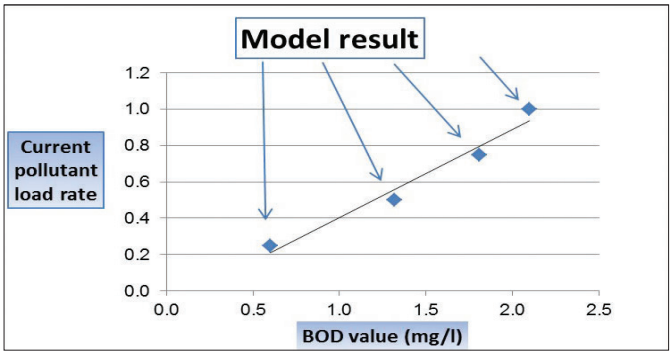


Figure 2. Relationship between pollution load discharged and concentration at the representative point (According to Decision 154/QD-TCMT, 2019 [6])

2.3. Data source

- Meteorological and hydrological data: Collected from stations as Cau Lau, Nong Son, Thanh My, Tam Ky and Son Tra between 2016 to 2018 and additional hydrological measurement data at Tam Ky river and Lo estuary when carrying out the national project with topic code: DTDL. CN-15/16 (Phase 1: From August 17, 2017 to August 22, 2017; phase 2: From August 16, 2018 to August 23, 2018) [4].

- Data of cross-section, terrain of Truong Giang Riverbed: Used from the project of building a flood map downstream of Vu Gia - Thu Bon River basins in 2018 and the dredging project of Truong Giang River [5,7]. The terrestrial one uses topographic map at 1:10,000-scale of Ministry of Natural Resources and Environment.

- Waste source data: Including 6 main sources, namely industry, living, aquaculture, livestock farming, soil leaching and 2 rivers of Thu Bon and Tam Ky, calculated from data of current development reports of each sector at Truong Giang River in 2017; Statistical Yearbook of 2017 for 4 districts [2, 3].

- Water quality data: Using the quarterly monitoring data of Quang Nam Department of National resource and Environment over the period of 05 years from 2014 to 2018. For supplementing data of water quality and serving verification and calibration, surface water samples were collected in 2 times (at the project with code number DTDL.CN-15/16) [4]. Phase 1: From November 15, 2016 to December 10, 2016 (rainy season); Session 2: From March 29, 2017 to April 21, 2017 (dry Season). Nine sampling positions locate in all the 4 river sections (sectionI: 02 points, section II: 02 points, section III: 03 points and section IV: 02 points); and the frequency was 5 times each point and the total was 90 samples. Water samples were collected and preserved in accordance with TCVN 6663-6: 2008, TCVN 6663-3:2016. The analysis of criteria BOD_5 and NH_4^+ was carried out at the Environmental Analysis Laboratory of Center for Monitoring and Modeling Research. environment (334 Nguyen Trai, Thanh Xuan, Ha Noi).

3. Results and discussion

3.1. Set up the MIKE 21 Ecolab model

Within the scope of this study, the Ecolab water quality model was established at Level 4 (MIKE 21 WQ Level 4) to simulate water quality for BOD and NH_4^+ parameters. This model level is suitable for studies on the effects of waste sources from urban, industrial and agricultural activities on water quality [11].

- Setting the calculated domain range of the model was limited from latitude X: 532099 to latitude X: 575086, from longitude Y: 1705442 to longitude Y: 1761194. The calculated domain scale has a range of 54km in the direction North-South, from 1-7km in the direction of East-West. The number of grid cells is 39,783 and the number of grid nodes is 21,695 with the smallest grid area is 167m^2, the largest grid area is 2.3 km^2 (Figure 3).

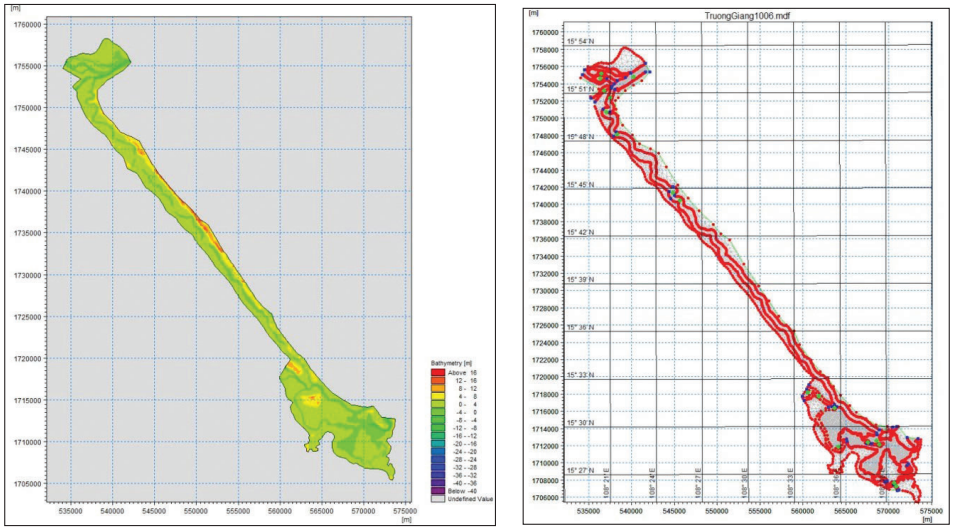
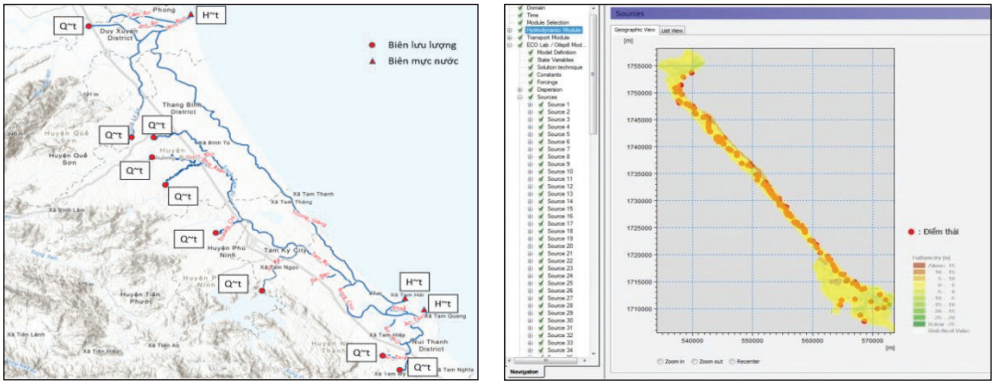


Figure 3. Topographic and grid area set for the Truong Giang River

- Setting boundary conditions:

+ Discharge and water level boundary: Including 09 flow boundary (at Thu Bon, Ly Ly, Tam Ky, Ngoc Kho, Phu Xuan, Truong Chi, Ba Ky and An Tan 2 (2 borders)), calculated from the overall picture of the Vu Gia - Thu Bon River basin [5] and 03 water boundaries at the 3 estuaries;

+ Waste source boundary: Based on the distribution characteristics of the 6 main sources of waste from socio-economic development, hydrological network, and topography of the river, the study has put into place 115 waste discharge points across the domain set.



a) Network diagram *b) Location of discharged points*

Figure 4. Establishing MIKE 21 model boundary conditions for Truong Giang River

3.2. Calibration and verification

Calibration and verification for MIKE 21 HD

The calibration of parameters of hydraulic model was mainly done by changing Manning's roughness coefficient and initial values. After calibrated the parameters, the model ensured the necessary accuracy with the calculated time step of 1 hour, roughness in the range of 0.02-0.035. The hydraulic model was calibrated with data series at the monitoring station on Tam Ky River from August 17, 2017 to August 22, 2017.

The calibration was assessed through correlation between measured and simulated water level (R^2) and errors between actual measurements and station calculations (NASH indicator), with the value of R^2 = 0.94 and the index NASH = 0.94.

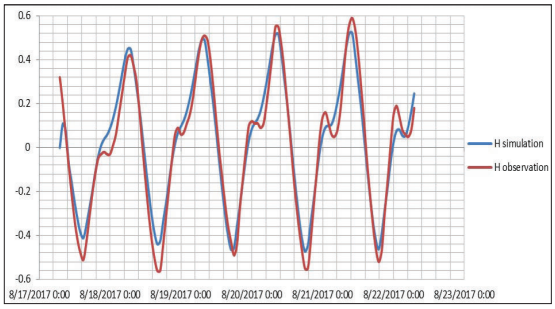


Figure 5. Simulated and measured of water level at the hydrology station on the Tam Ky River when calibration the model

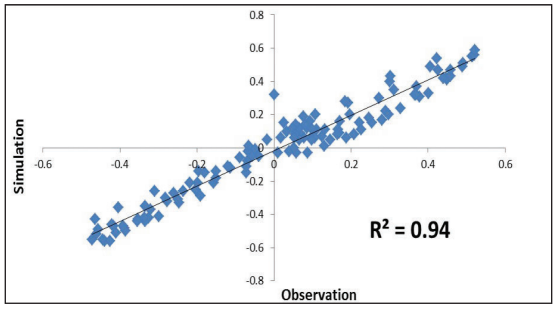


Figure 6. Relationship between simulated and measured water level at the hydrology station on the Tam Ky River when calibration the model

The purpose of verification was to assess the suitability of the parameters in the verification. The study used the actual water level data measured in the dry season (August 2018) at the hydrographic observation station of the Tam Ky River for verification.

Verification resulted the value R^2 = 0.90 and the NASH index = 0.88.

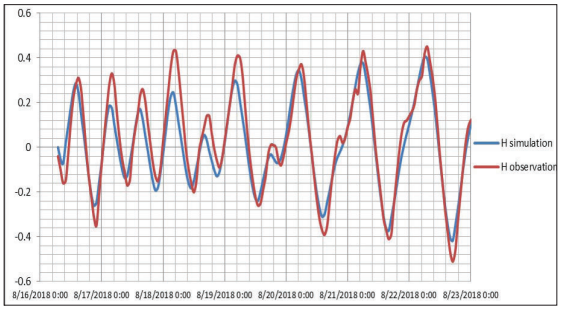


Figure 7. Simulated and measured water levels at the hydrology station on the Tam Ky River when verification the model

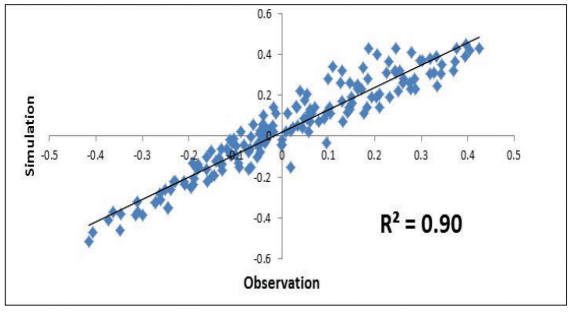


Figure 8. Relationship between simulated and measured water level at the hydrology station on the Tam Ky River when verification the model

The relatively high R^2 values and NASH coefficients show that the calibration and verification were very good. With the above calibration and verification results, the mathematical model shows the reliability of the calculated results.

Calibration and verification for water quality models, MIKE 21 Ecolab

The calibration was also evaluated by the correlation between observed and simulated values (R^2) and errors between monitoring data and calculations at 9 cross-sections (NASH) of the parameters. Specifically, the value of NASH (BOD)=0.66; R^2 value (BOD)=0.64; NASH (NH_4^+)=0.73; R^2 value (NH_4^+)=0.78.

Verification resulted the value NASH (BOD)=0.65; R^2 value (BOD)=0.62; NASH (NH_4^+)=0.75; R^2 value (NH_4^+)=0.76.

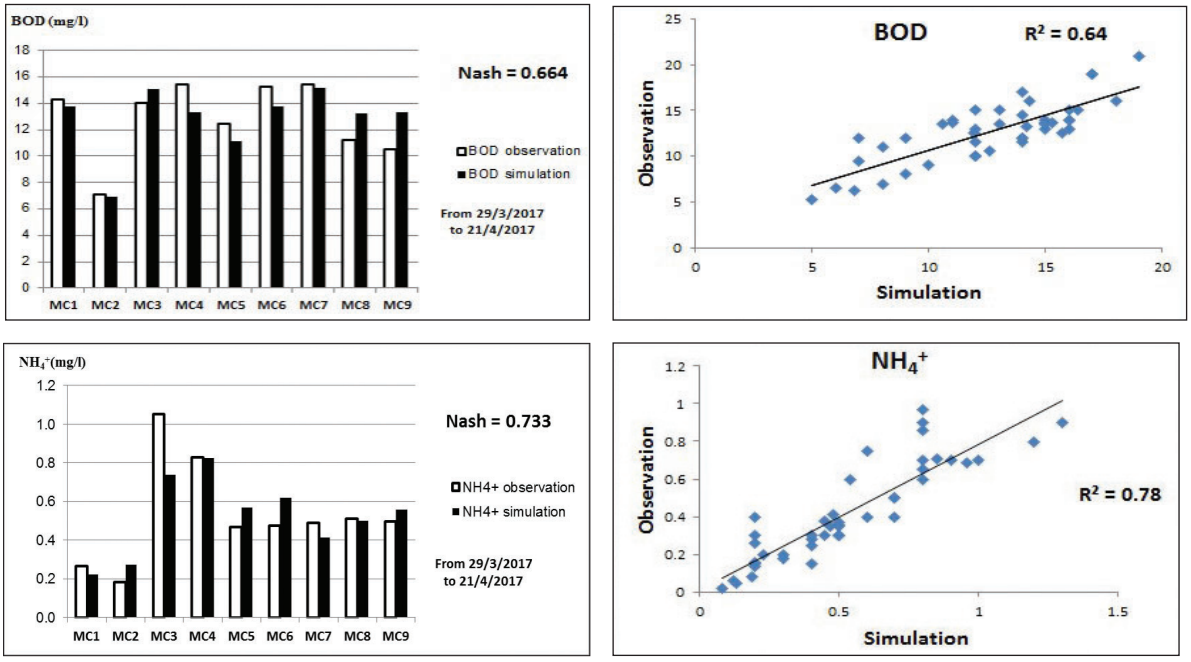


Figure 9. Relationship between simulation and measurement of the values of BOD, NH_4^+ values when calibration the model

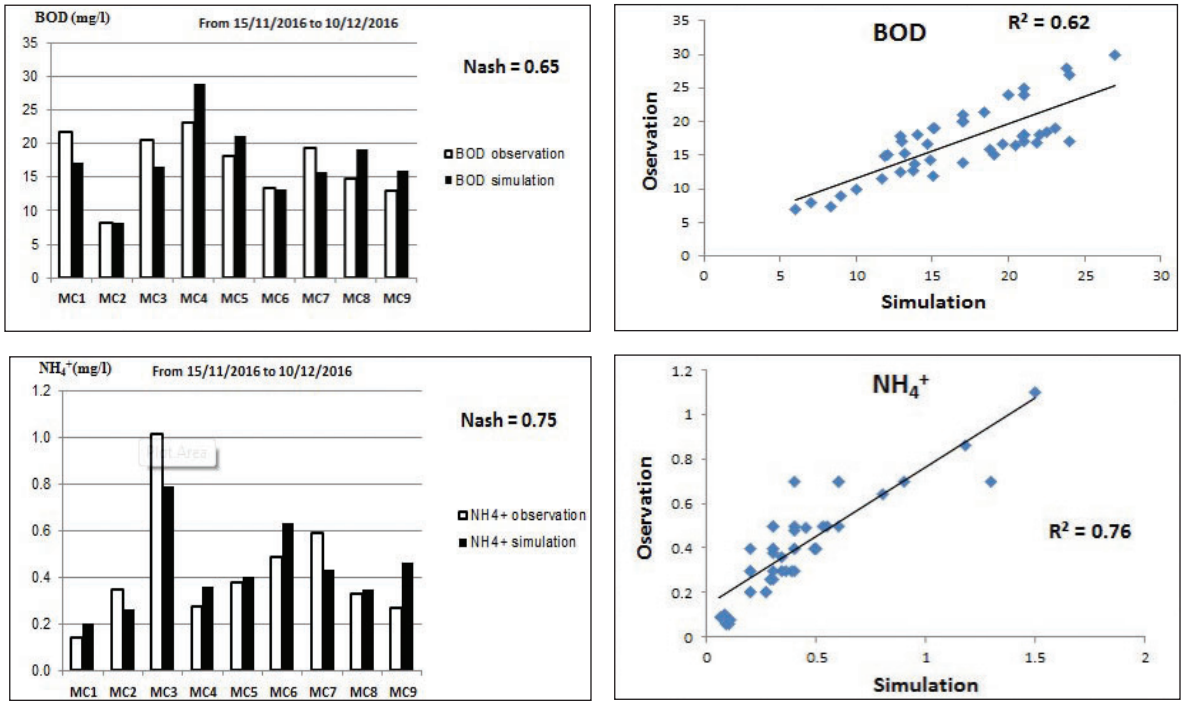


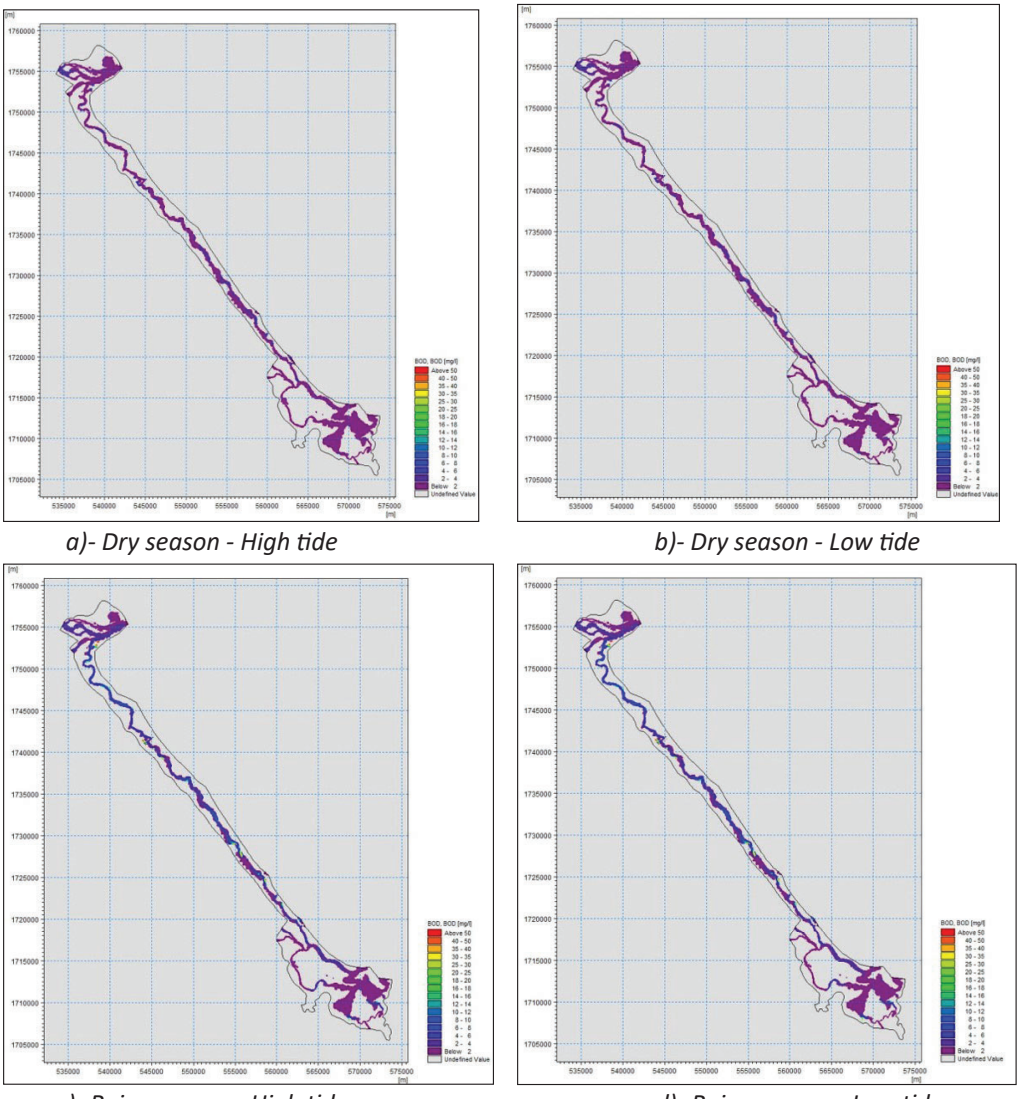
Figure 10. Relationship between simulation and measurement of the values of BOD, NH_4^+ values when verification the model

The NASH values ranged from 0.65 to 0.75, the determination coefficient R^2 was from 0.62 to 0.78, showing that the calibration and verification were quite good, the model shows reliability on the calculation results.

3.3. Pollutant carrying capacity of Truong Giang River

• ***The contaminant concentration on the Truong Giang River***

Simulation results of water quality of the Truong Giang River in 2017, using MIKE 21 model, show that BOD value varies widely among river sections, section III had the largest variation from 1.55 to 80.84mg/l, section IV (1.27-54.4mg/l), section II (1.89-29.17mg/l), the lowest was in section I (1.35-27.12mg/l). The average BOD value was not much different among the sections and mostly satisfied QCVN 08-MT:2015/BTNMT at B1-level. The BOD of the sections in the rainy season was higher than that in the dry season but not much. The reasons were the higher flow from the two rivers of the Thu Bon and Tam and the higher washing away of soil in the rainy months, from October to December. In addition, the amount of organic matter discharged into the river was quite large, while in the dry season, the seawater from the tides had contributed to cleaning up the organic matter in the river water.

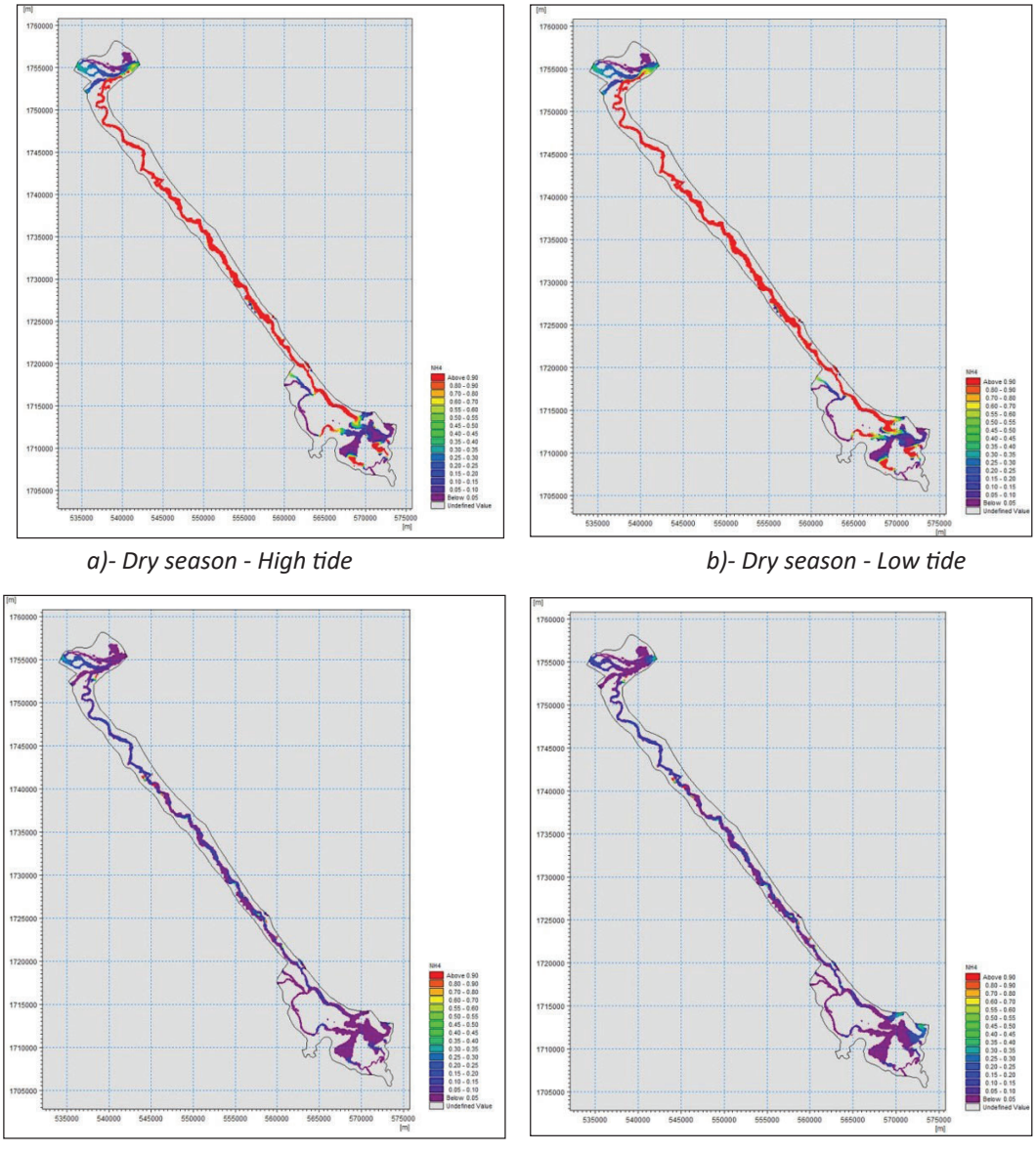


a)- Dry season - High tide *b)- Dry season - Low tide*

c)- Rainy season - High tide *d)- Rainy season - Low tide*

Figure 11. BOD value in the Truong Giang River according to seasons and tides
Notes: Dry season: April - June, 2017; rainy season: October - December, 2017;
High tide: From the time of the lowest tide level to the highest level of the day;
Low tide: From the time of the highest tide the water falls to the lowest of the day.

NH_4^+ value in the sections: Section I (0.07-3.07mg/l), Section II (0.04-3.6mg/l), Section III (0.05-4.79mg/l) and section IV (0.04-2.7mg/l). Simulation results of NH_4^+ in the dry season were higher than those in the rainy season. Section III had the highest concentration of NH_4^+, especially in section II, although the pollution load discharged into this section was quite low compared to other sections. Due to the narrow riverbed, and sedimentation, the flow of water through the section was low (average flow about 15-18m^3/s), reducing the ability to dilute and self-purification of water body, leading to high NH_4^+ value.



a)- Dry season - High tide

b)- Dry season - Low tide

c)- Rainy season - High tide

d)- Rainy season - Low tide

Figure 12. NH_4^+ value in Truong Giang River according to seasons and tides

Pollutant carrying capacity according to scenarios

After calibration and verification, the MIKE 21 Ecolab model was used to simulate and calculate for different scenarios. The development of a correlation function of pollution load discharged into each section of the Truong Giang River and the value of pollution parameters at the

representative point of the section, thereby determining the pollution carrying capacity of each river section in kg/day. Based on the guidance in Decision 154/QD-TCMT [6], the study identified a representative point that coincided with the location of 9 water quality monitoring sections of 4 sections. Based on the limit value of surface water quality parameters according to QCVN 08-MT: 2015/BTNMT levels A2, B1, B2, we set up three scenarios to determine the pollutant carrying capacity of the Truong Giang River (Table 1).

Table 1. Scenarios of determining pollution carrying capacity of the Truong Giang River

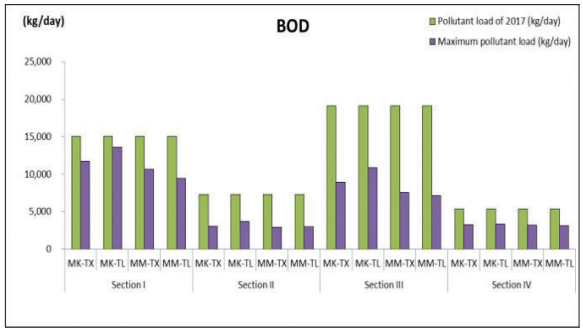
No.	Scenario	Limited value of parameters	The purpose
1	**Scenario 1.** Pollutant carrying capacity under A2 scenario (scenario for restoring river functions)	BOD ≤ 6 mg/l NH_4 ≤ 0.3 mg/l	In order to determine the ability of receiving pollutants into the Truong Giang River so that the river can restore some of previous functions which are no longer meeting such as aquaculture, domestic purposes and restoring valuable aquatic resources.
2	**Scenario 2.** Pollutant load capacity under scenario B1 (scenario for maintenance of current function)	BOD ≤ 15 mg/l NH_4 ≤ 0.9 mg/l	Assessing the ability to receive pollutants in the threshold of maintaining current functions of the Truong Giang River such as water supply for agriculture, water transportation, aquaculture and other equivalent functions.
3	**Scenario 3.** Pollutant carrying capacity under B2 scenario (Bad scenario)	BOD ≤ 25 mg/l NH_4 ≤ 0.9 mg/l	This is a warning, aiming to determine the maximum emission threshold of development fields so that Truong Giang River will not become a "dead river", meaning losing the ability to regenerate and restore. Beyond this limit, water quality does not meet any water use function.

Scenario 1. *Pollutant carrying capacity under A2 scenario (scenario for restoring river functions)*

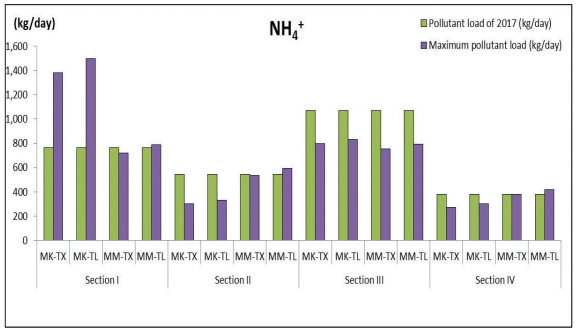
The results showed that the BOD load exceeded the maximum load from 1,430kg/day in section I (equivalent exceeded 10% of the base load in 2017) to 11,950kg/day in section III (equivalent exceeded 63%). For the parameter of NH_4^+, while section I was still capable of receiving 334kg/day (reaching 44% of the base), section II, section III and section IV are no longer able to receive pollutant (exceeding 105kg day, 280kg/day and 37kg/day, respectively) (Figure 13).

Compared to other sections, section I has the best load capacity, followed by sections IV and III. Section II has the lowest carrying capacity despite having a lower pollutant discharge load compared to other sections. Section II, which the riverbed was narrowed with strongly deposited, leading to the low flow of water sources, it is necessary to have solutions for dredging, clearing the flow, increasing the o pen-surface and the water depth. Seasonally, the carrying capacity in the dry season was higher than that in the rainy season for parameter BOD, and the trend of NH_4^+ was reverse. This result is suitable for the change in seasonal pollutant concentration of the two parameters.

Under this scenario, in order to meet the requirement in QCVN 08-MT:2015/BTNMT at A2-level, it was necessary to reduce by 20,358 kg BOD per day and 421kg NH_4^+ per day. For aquaculture, domestic and livestock farming sources, reductions can be made by increasing the efficiency of wastewater treatment before being discharged into the river (especially from aquaculture); For industrial source, it was necessary to maintain the existing treatment efficiency and prevent environmental incidents, and to control efficiently the waste sources in upstream river systems (Thu Bon and Tam Ky Rivers).



a)- BOD carrying capacity of scenario A2

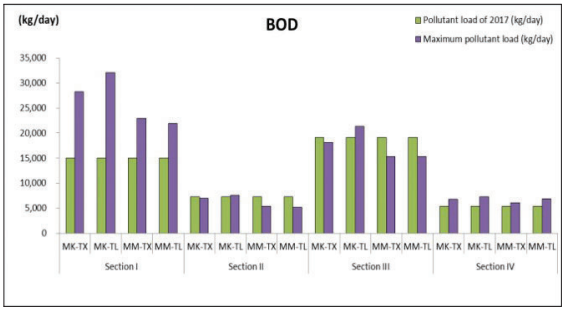


b)- NH_4^+ carrying capacity of scenario A2

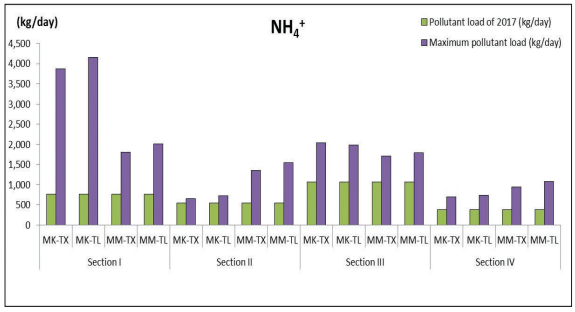
Figure 13. Pollutant carrying capacity of Truong Giang River under scenario A2
Notes: MK: Dry season; MM: Rainy season; TX: Low tide; TL: High tide.
Section I: The section of Duy Xuyen - Thang Binh; Section II: The section of Thang Binh;
Section III: Thang Binh - Tam Ky - Nui Thanh; Section IV: Truong Giang lagoon.

Scenario 2. *Pollutant carrying capacity under scenario B1 (scenario for maintenance of current function).*

In scenario B1, the 4 sections were still capable of receiving pollutants, except for BOD in the rainy season in sections II and III, at 1,910kg/day and 3,767kg/day respectively. Compared to scenario A2, the pollution receiving capacity under this scenario with BOD, NH_4^+ increased by 7,622kg/day and 1,025kg/day, respectively (Figure 14).



a)- BOD carrying capacity of scenario B1



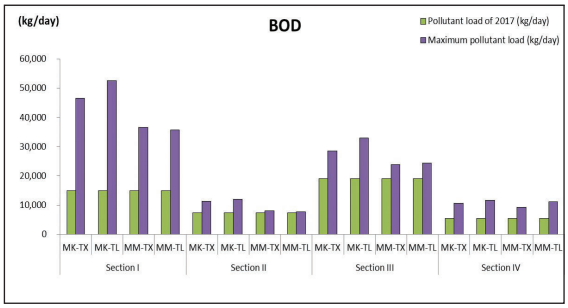
b)- NH_4^+ carrying capacity of scenario B1

Figure 14. Pollutant carrying capacity of the Truong Giang River under scenario B1

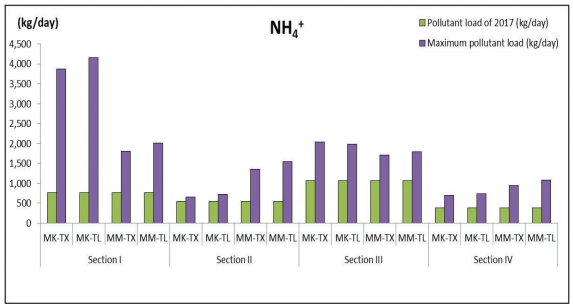
Scenario 3. *Pollution carrying capacity under B2 scenario (Bad scenario).*

Under this scenario, the 4 sections were still capable of receiving pollutants for the parameters. Compared with the scenario B1, the carrying capacity of BOD increased by 4.3 times while NH_4^+ did not change (Figure 15).

In order to ensure the minimum threshold of water quality in Truong Giang River (QCVN 08-MT: 2015/BTNMT at B2-level) for functions such as water transport and flood drainage without losing the ability to regenerate and recover, it was necessary to limit the amount of pollution load discharged into the Truong Giang River by reducing by 1.94 times of BOD and 2.45 times of NH_4^+ of the base year (2017).



a)- BOD carrying capacity of scenario B2



b)- NH_4^+ carrying capacity of scenario B2

Figure 15. Pollutant carrying capacity of Truong Giang River under scenario B2

4. Conclusion

For Scenario 1 corresponding to the water quality at level A2-QCVN 08-MT:2015/BTNMT, section I had the best capacity, followed by sections IV and III. Section II had the lowest capacity, due to the narrowing of the riverbed, strong sedimentation and low water flow. Under Scenario 2, the 4 sections were still capable of receiving pollutants, except for BOD in section II and III in the rainy season. For Scenario 3 with the lowest requirement of water quality, it was necessary to limit the amount of load discharged into Truong Giang River to not exceed 1.94 times of BOD and 2.45 times of NH_4^+ load of the base year. By this result, in order to improve the quality of water and ability of the carrying capacity, there should be further studies to zone the function of water resources of the River in each section, combine solutions of management and waste treatment from sources, especially the source of aquaculture along the river to ensure the regeneration and recovery ability of the River.

Acknowledgments: *The authors sincerely thank for the support of the state-level project "Overall study of Truong Giang River and surrounding areas for socio-economic sustainable development of Quang Nam province", code DTDL.CN-15/16 and project "Assessing the impact of climate change on natural conditions, natural resources and the environment in the coastal estuaries of the Red River Delta and proposing solutions proper use of exploitation methods", code BĐKH.33/16-20 provided the source of data and technical support for the authors to implement the article.*

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