MINISTRY OF EDUCATION AND TRAINING
MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT
VIETNAM ACADEMY FOR WATER RESOURCES

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STUDY OF THE IMPACT OF TYPES OF SOURCES OF DISCHARGE TO QUALITY SURFACE WATER OF CA MAU PENINSULA

SUMMARY OF THE DOCTORAL THESIS OF ENGINEERING

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Introduction

I. Objectives of study

- Assess the primary sources of wastewater (industry, agriculture, and domestic wastewater) discharged into the river and canal system in the Ca Mau Peninsula;

- Establish a scientific foundation for assessing and disseminating the primary sources of waste causing water pollution in the Ca Mau Peninsula.

- Determine the impact and distribution of wastewater sources in the study location.

II. Scientific significance of the thesis

The results of the thesis research will provide a scientific foundation and methods for analysing and quantifying the level of discharge (from the major sources), the spread of each type of source, and the grouping of pollution sources. Surface water pollution in rivers and canals as a result of sources at the study area's border. The impact of each form of discharge source on the quality of surface water in rivers and canals can then be evaluated.

III. Practical significance of the thesis

- The research results of the thesis are used as a reference to warn of surface water pollution in rivers and canals in the study area serving domestic water supply, agriculture and aquaculture in the study area;

- The research results of the thesis are also used as a reference by agencies managing water resources and protecting the water environment in planning for the development of surface water resources, land use, and sustainable water management. The

socioeconomic growth of the sample area and other regions with similar conditions.

IV. The new points of the thesis

(1) Clarification of the categories of discharge sources (quantity and quality) into rivers and canals in the Ca Mau Peninsula, assessment of the distribution of discharge sources, and identification of the major pollutant components in domestic, industrial, and agricultural wastewater. industry and aquaculture;

(2) Clarifying the trend of spreading water sources from the border (Hau River, Sea border) into the Peninsula and the trend and extent of spreading wastewater discharge within the peninsula, thus assessing the trend and extent of spreading wastewater. Transmission, influence, and contamination of water sources on the peninsula;

(3) Identify polluted areas based on hydraulic characteristics (flow, water intake direction, discharge direction, etc.) and water quality to identify the principal problems for the surface water environment and identify solutions to improve the environment on the peninsula.

CHAPTER 1. OVERVIEW OF THE IMPACTS OF WASTE SOURCES ON SURFACE WATER QUALITY IN THE WORLD AND CA MAU PENINSULA

1.1. Overview of surface water quality

The discharge of untreated effluent into water sources causes severe pollution of surface water sources in developing nations, where water pollution is increasing most rapidly. The vast majority of human activities, production activities, etc., have the capacity to pollute the environment, including the water environment.

1.2. Overview of discharge sources

The water pollution in the study area is caused by a variety of factors (both human and natural), including the reception of refuse from discharge sources into receiving sources and the transmission of pollutants in the aquatic environment. For the Ca Mau Peninsula, the primary source of surface water pollution in the study area is domestic, industrial, agricultural, and aquaculture effluent directly discharged into surface water (untreated or substandard)...

1.3. Overview of studies pertaining to discharge sources and surface water quality in the Ca Mau Peninsula

Comparatively little assessment of the impact of refuse sources on water quality has been conducted worldwide. The research outcomes serve as the scientific foundation for evaluating the effects of discharge on surface water quality. Since then, solutions to surmount surface water pollution in the Ca Mau Peninsula have been proposed while also emphasizing the role of freshwater sources used to push salinity and clean the system.

There are still numerous flaws in the application of computational hydraulic models of water quality to the study location. The propagation of water resources containing nonconservative substances has not yet been investigated, and the implementation of hydraulic and water quality models to predict water quality trends is still limited, but this is not the case. is a crucial aspect of pollution warning.

This thesis will employ the theory of propagation of water sources in river and canal systems to address the aforementioned issue. To supplement and improve the current calculation tool and

methodology for water assessment, based on the concept of analysing the water system through its component water sources. The thesis will calculate the distribution of water sources using the MIKE11-Ecolab Model.

1.4. Define and limit the research problem of the thesis

From the above analysis of extant research problems, it is possible to identify the following thesis research problems:

(1) Assessment of sources of pollutant discharge into the Ca Mau Peninsula river/canal system (quantification of sources for current and prospective trends). Simultaneously, the impact of each form of discharge source on the Ca Mau Peninsula's water quality is evaluated.

(2) The water quality regime is examined under the influence of intrapeninsular discharge sources and boundary conditions, in which the spread and distribution of some important water sources for the SCA are observed to determine the spread and impact scope (direction, scope, rate of polluted water sources over time) of each type of source and group of polluting sources.

(3) Provide direction for technical solutions to control effluent (based on discharge source impact).

CHAPTER 2. SUBJECTS AND RESEARCH METHODS

2.1. Objectives and scopes of the study

2.1.1. Scope of the study

The study area encompasses the entire Ca Mau Peninsula, located south of the Cai San canal and on the right bank of the Hau River, with a total natural area of approximately 1,678,000 hectares (representing approximately 43% of the Mekong Delta's land area). Includes Can Tho city, Hau Giang, Soc Trang, Bac Lieu, and Ca Mau provinces, as well as the southern portion of Kien Giang province (including Giong Rieng, An Bien, An Minh, Vinh Thuan, and Go Quao districts and southern communes) Chau Thanh and Tan Hiap districts.

2.1.2. Subjects of the study

The subject of this study is surface water and wastewater in the Ca Mau Peninsula, including surface water (water from the Hau River and the East and West Seas). The primary sources of polluting effluent are domestic, industrial, agricultural, and aquacultural sources. Objects that discharge effluent at a rate of 50 m^3/day; and the quality of surface water in the Ca Mau peninsula.

There are two primary categories of pollution sources on the Ca Mau Peninsula: point sources and dispersed sources. It is simple to identify point source pollution because it originates from a singular location. Distributed source pollution is more difficult to identify and manage because it originates from multiple locations simultaneously (e.g., agricultural effluent, stormwater runoff).

- There are 552 point discharge sources, of which 144 waste sources have a flow greater than 50 m3/day and night; 408 small refuse sources from establishments located outside the industrial area; and 144 waste sources with a flow greater than 50 m^3/day. (The facilities are dispersed along the river and channels);

- Distributed sources are sources that originate from multiple locations simultaneously (e.g., agricultural effluent, stormwater runoff) and are difficult to identify and control. According to the Water Resources Planning of the Ca Mau Peninsula, there are 52 irrigation subregions, which correspond to dispersed waste sources (cultivation and aquaculture) that discharge into 135 primary rivers and channels in the region (irrigation subregions are also the major areas in the region). respective husbandry).

2.2. Research methods

2.2.1. Field measurement, sampling and analysis

- Standards for evaluating the quality of water: National technical regulation governing the purity of surface water QCVN 08-MT:2015/BTNMT;

Methods for sampling and monitoring: Conforming to the TCVN 6663 (ISO 6667) standard. Quality of water - sampling.

2.2.2. Method of calculating wastewater flow

- To determine the total amount of wastewater generated in the entire region for each source, the thesis will compute the amount of wastewater generated from the four major wastewater sources: domestic, industrial, agricultural, and aquaculture. Based on the causes of surface water pollution in the Ca Mau Peninsula, the above four sources of effluent are primarily to blame.

+ The quantity of domestic wastewater is anticipated based on the 2016 population and current domestic water usage standards;

+ Calculation of industrial wastewater: In accordance with TCXDVN 33:2006 on water supply - pipe network and standard design works (Ministry of Construction), water use standards for industrial production requirements are determined based on existing design documents or comparisons to similar conditions.

+ The quantity of crop wastewater is the amount of water that flows out of the fields as a result of excessive water drainage or natural leakage (return water volume). According to global and Vietnamese studies, the regression coefficient is approximately 15%. The quantity of wastewater generated by livestock is estimated using the number of livestock and poultry as well as the coefficient of wastewater generation.

+ Calculation of aquatic wastewater: According to Decision 88/QD-UBND dated January 13, 2014, of the People's Committee of Binh Duong province directing the collection and calculation of environmental directives for the period 2013-2020.

+ The amount of wastewater from aquaculture is the amount of water that flows out of the ponds due to drainage or natural leakage.

2.2.3. Calculation of the pollutant load

Pollution load is the quantity of a pollutant present in effluent or a water source over a given time period. To calculate the Ca Mau Peninsula's pollutant load, the discharge sources include domestic, industrial, livestock, and aquaculture sources. According to Ministry of Natural Resources and Environment Circular No. 76/2017/TT-

BTNMT (Regulations on assessment of effluent receiving capacity, load capacity of river and lake water sources).

2.2.4. Method of calculating the surface water quality index (WQI)

Vietnam's water quality index (VN_WQI) is an index derived from surface water quality monitoring parameters in Vietnam that is used to quantify water quality and the utilization of water resources. which is reflected by a scale. The water quality index is computed on a scale (6 WQI value ranges) corresponding to the icon and color to alert the user of the water's suitability for use.

2.2.5. Modelling Methods

Using the Mike11-Ecolab model for the Ca Mau Peninsula region to simulate and predict the spatial and temporal evolution of surface water quality on the river/canal system. As a basis for evaluating the impact of the major effluent sources (domestic, industrial, agricultural, and aquaculture) on the surface water quality.

As a premise for assessing the scope and extent of impacts, a mathematical model of water spread is used to calculate the spread of polluted water sources in the area and water sources spreading from the boundary of the study area into the systems. the influence of each pollution source and water supply from the boundary.

2.2.6. Bayes method

The Bayes method (BMA) uses the Bayesian factor (BF) and the index to assess the "compromise" between the model's complexity and predictability (BIC) to select the optimal model.

In this study, there are numerous water quality parameters (BOD5, DO, NH4+, total coliform, etc.) that determine pollution, i.e., water quality (the WQI value). This method will determine which

variables (parameters of water quality) are associated with the WQI. From there, the water quality simulation parameters for the study area were determined.

2.2.7. Machine learning method

The study uses machine learning models to calculate (predict) WQI with 2 main groups: reinforcement algorithms and decision tree algorithms because these are two algorithms that give high-precision calculation results. The algorithm is easy to understand and easy to implement.

The aforementioned research and calculation methodologies can be summarized using the diagram in Figure 2.1.

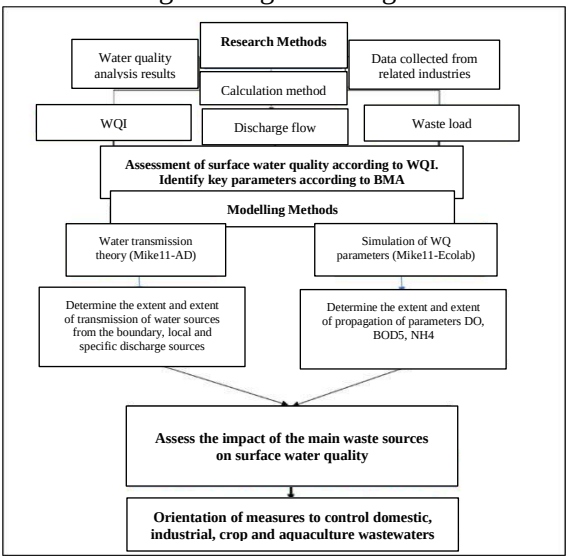

Figure 2.1: Diagram of the research method

CHAPTER 3. RESULTS OF RESEARCH AND DISCUSSION

3.1 Study to identify the source of waste in Ca Mau Peninsula

3.1.1 Calculation of Wastewater Flow

Domestic wastewater, industrial wastewater, medical wastewater, and livestock wastewater are a few of the primary sources of wastewater generation that are calculated in the thesis. Through calculations, it has been determined that the total amount of wastewater generated (domestic, industrial, agricultural, and aquaculture) in the BCC in 2016 was estimated at 3,506,796 m3/day; in 2030, it is estimated to be 3,375,070 m3/day-night, a decrease of 3.75 percent compared to 2016 (primarily due to the reduction of wastewater from agriculture as a result of the reduction in cultivation area). Ca Mau discharges the greatest quantity of wastewater into rivers and canals (29.0%), followed by Soc Trang (18.0%), Bac Lieu (17.2%), Kien Giang (16.2%), Can Tho (10.5%), and Hau Giang (8.5%). See Figure 3.1.

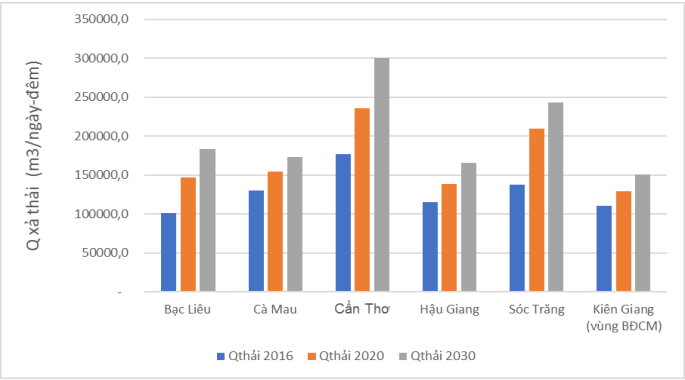

Figure 3.1: The chart compares the total amount of wastewater in the Ca Mau Peninsula area

3.1.2 Calculation of the pollution parameter load

According to the above calculations, domestic, industrial, agricultural (crop) and aquaculture waste sources are the main sources of pollution for the region. Therefore, the main emission sources included in the pollutant load calculation include domestic, industrial, livestock and aquaculture waste. The components selected to calculate the pollutant load are BOD_5, COD, TSS, total N, and total P because these are also typical pollution parameters of the Ca Mau Peninsula.

Through calculation results of wastewater flow and pollutant load of waste, it is found that the main sources of wastewater affecting the water quality of the study area are domestic, industrial, farming and aquaculture wastes.

3.2 Assessment of surface water quality according to the surface water quality index (WQI)

3.2.1 Results of surface water quality monitoring

Through the monitoring results, it is found that the surface water in the study area is mainly polluted with organic matter, nutrients and microorganisms. The parameters that repeatedly exceed permissible standards are DO, BOD_5, NH_4^+ and total coliform (these are also typical pollution parameters of the study area). In addition, TSS in the country is also high due to a large amount of alluvial from floods during the year. The level of organic pollution, nutrients and microorganisms has been increasing over the years (surpassing permissible standards from 1.1 to 3.7 times).

3.2.2 Surface water quality index (WQI) calculation results

Through the calculation results of VN_WQI, it can be seen that the area affected by surface water pollution is very large (accounting for approximately ½ the area of the whole region): the Northeast (Can Tho City); the Southeast (Soc Trang – Bac Lieu); the West (An Minh district, An Bien, Kien Giang province) and the middle of the Peninsula (Vi Thanh, Ca Mau).

The canals affected by pollution are the Ca Mau – Bac Lieu Canal, Quan Lo - Phung Hiep Canal, and Canals in urban areas of large urban areas (Can Tho and Soc Trang). For the provinces in the study area, the fluctuation margins of VN_WQI are also very different; Hau Giang, Soc Trang, Kien Giang and Can Tho provinces have low WQI values and large fluctuation margins (which means more serious pollution); the two provinces of Bac Lieu and Ca Mau have VN_WQI values greater than 50, so the quality of surface water is not seriously polluted. However, Ca Mau province has a few local pollution points (mainly in Ca Mau city due to wastewater from domestic and industrial activities).

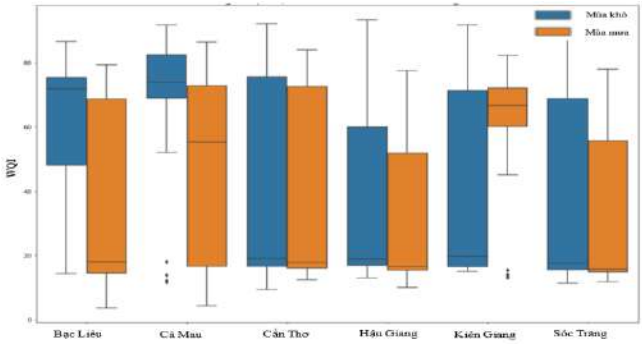

Figure 3.2: Chart of WQI fluctuation amplitude of provinces in the Ca Mau Peninsula (April and October 2016)

3.2.3 Surface water quality index prediction by machine learning

Based on the results of selecting parameters for building machine learning models by the Bayesian method (BMA), the study selected Model 1 with 4 parameters, pH, BOD5, PO4 and coliform, as the input data. into WQI prediction by 4 machine learning algorithms (models). The WQI forecast results show that the gradient boosting model has the most accurate prediction results because it has the highest coefficient of determination R^2 (0.973) and the lowest values of errors MAE, MSE and RMSE (3.24; 22.54; 4.75). Next is the eXtreme Gradient Boosting model with an R^2 of 0.966 and corresponding error values (3.15; 28.95; 5.38). The decision tree model has an R^2 of 0.944, and the error values are 4.46, 49.67, and 7.04. The light boosting model has an R2 of 0.928, and the error values are 5.95, 63.30, and 7.95.

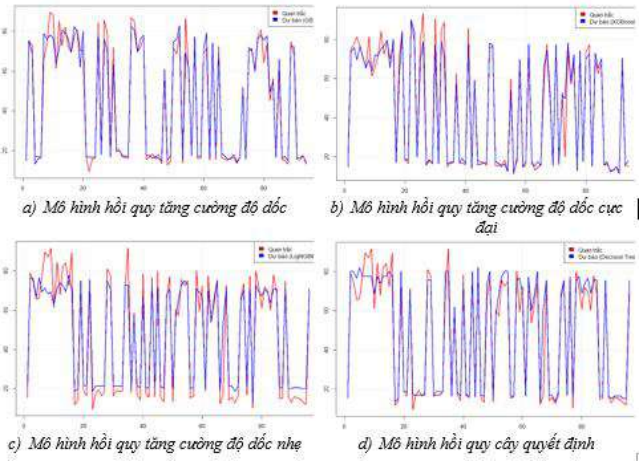

Figure 3.3: Comparison chart between predicted and actual WQI values

3.3 Study on the spread of water sources in the Ca Mau Peninsula

3.3.1 Types of surface water and wastewater sources

The water quality of the study area is a result of the interaction of all water sources from the peninsula's boundary and interior (surface water and waste) (Figure 3.3):

- Water sources from the border of the Ca Mau Peninsula include the Hau River (from upstream), the East and West Seas, and the Hau River (from downstream).

- The internal sources of the peninsula include the main sources of waste: domestic, industrial, agricultural, and aquaculture;

- Specific sources (arising in a certain time period), such as wastewater from aquaculture areas and environmental incidents.

- Specific sources (arising in some time) such as wastewater from aquaculture areas, environmental incidents...

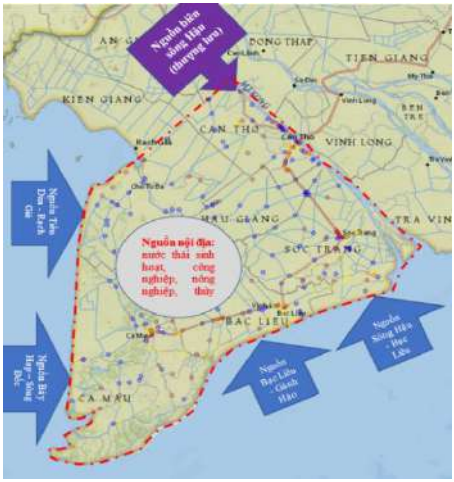

Figure 3.4: Diagram of the extent of marginal water sources of in the Ca Mau Peninsula

3.3.2 Research on the propagation of sources along the border of the Ca Mau Peninsula

The simulation results indicate that surface water (fresh) from the Hau River (with a proportion of fresh water composition greater than 75%) penetrates deeply into the Peninsula, accounting for approximately 40-45% of the area of the CM along the canals of Cai San, Thot Not, O Mon, Cai Con to the Cai Lon River, Quan Lo - Bac Lieu canal, and the Nhu Gia River (Soc Trang); sea water source: East Sea sea water can penetrate very deeply. The West Sea sea current cannot penetrate deeply into the Peninsula, as it is much less than the flow from the East Sea (as the East Sea tide is stronger). Refer to Figures 3.5 through 3.8.

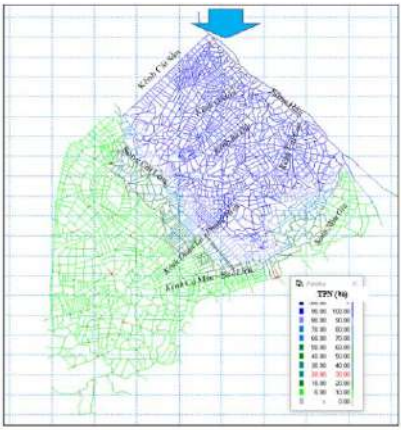

Figure 3.5: Distribution of the largest freshwater component of Hau river when there is a salt prevention works (1/2016)

Figure 3.6: Distribution of the composition of sea water from Hau estuary - Hoa Phu channel when there is a salt prevention works (1/2016)

Figure 3.7: Distribution of the composition of Bac Lieu – Ganh Hao seawater sources in the presence of salt prevention works (January 2016)

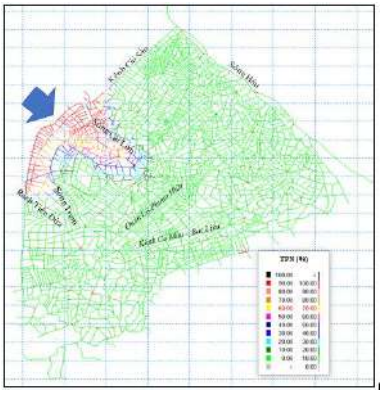

Figure 3.8: Distribution of seawater composition of Tieu Dua - Rach Gia in the presence of salt prevention works (1/2016)

3.3.3 Researching of inland sources of Ca Mau Peninsula

The following are the outcomes of the simulation of the propagation of sources in the vicinity of the Ca Mau Peninsula:

- Dispersion of domestic wastewater: The proportion of domestic wastewater composition, 20%, is widespread, accounting for approximately 80% of the entire peninsula;

- Industrial wastewater is distributed with relatively high concentrations near discharge sources and then spreads very widely in many directions;

- Spread of crop wastewater: The deeper into the peninsula, the percentage of this wastewater gradually increases and reaches a high value, up to 10%, even in large areas.

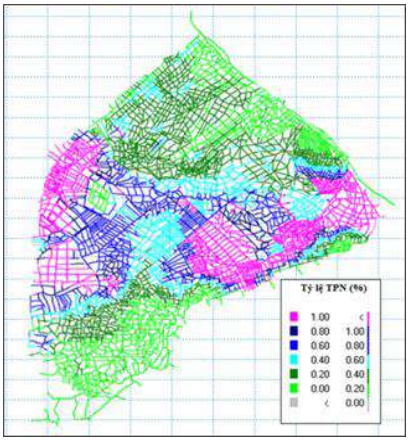

Figure 3.9: Spread map of domestic wastewater in Ca Mau Peninsula (1/2016)

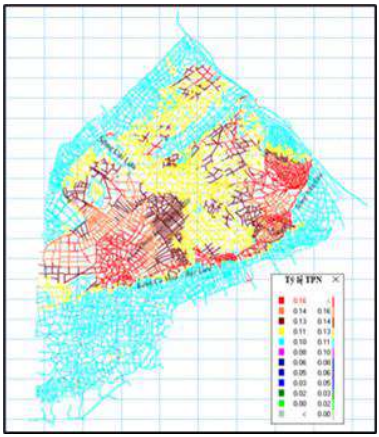

Figure 3.10: Spread map of industrial wastewater in Ca Mau Peninsula (1/2016)

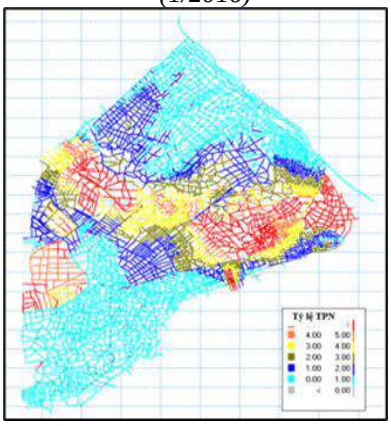

Figure 3.11: Spread map of crop waste water in Ca Mau Peninsula (January 30, 2016)

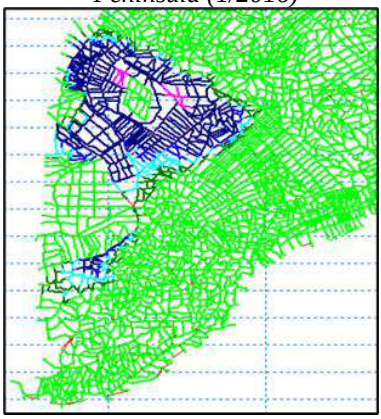

Figure 3.12: Percentage of aquaculture wastewater in Southern Ca Mau after 30 days

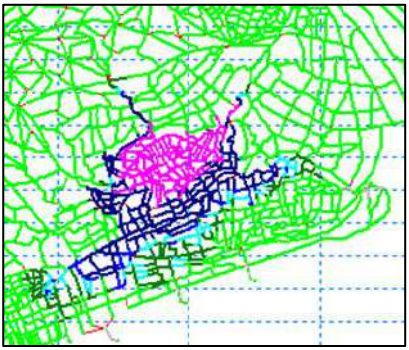

Figure 3.13: Percentage of aquaculture wastewater in My Xuyen area, Soc Trang province after 7 days

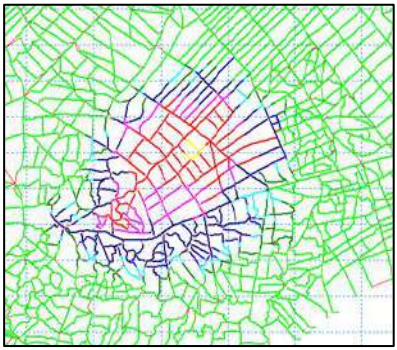

Figure 3.14: Percentage of aquaculture wastewater in the North of National Highway 1A, Bac Lieu province after 3 days

3.4 Simulation of water quality in Ca Mau Peninsula

3.4.1 Results of simulating water quality parameters using the MIKE11-Ecolab model

In this section, the surface water quality will be simulated and forecast on the river/canal system of the Ca Mau Peninsula in space and time for the three parameters DO, BOD_5 and NH_4^+ (which also have a significant impact on surface water quality in the Ca Mau Peninsula) to assess the impact of pollution sources on the surface water quality of the Ca Mau Peninsula in the current status quo (2016). Simulations of water quality parameters indicate that the most severely polluted areas are located in the western portion of the peninsula (west coast: Ca Mau and Kien Giang provinces) and the area between the Peninsula (Bac Lieu, Soc Trang) and the East Coast (primarily in Soc Trang province).

The results of the simulation parameters show that the heavily polluted area is concentrated mainly in the west of the peninsula (west

coast: Ca Mau and Kien Giang provinces) and the area between the peninsula (Bac Lieu and Soc Trang provinces) and the east coast (mainly in Soc Trang province).

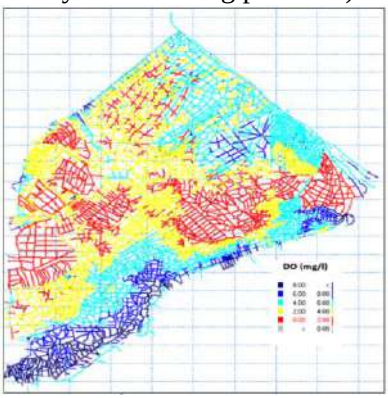

Figure 3.15: Simulation results of DO in Ca Mau Peninsula (January 2016)

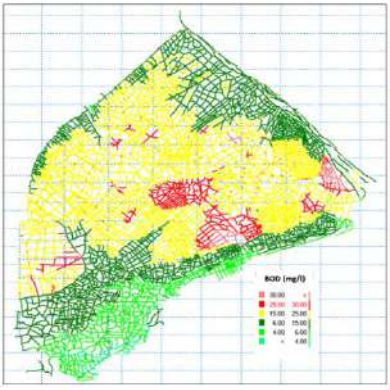

Figure 3.16: Simulation results of BOD_5 in Ca Mau Peninsula (January 2016)

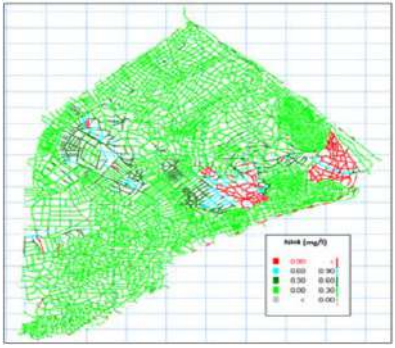

Figure 3.17: Simulation results of NH_4^+ in Ca Mau Peninsula (January 2016)

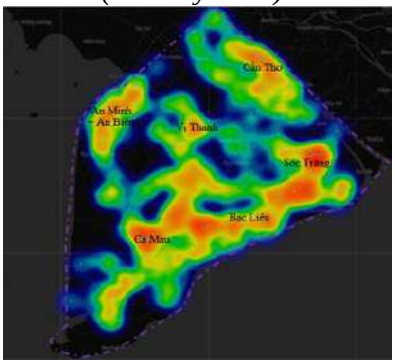

Figure 3.18: Area affected by surface water pollution

3.5 Evaluation of discharge source effects on water quality

Under the influence of the hydrological regime (aquaculture), the impact on surface water quality in the study area is primarily

attributable to pollutant discharge from activities such as daily life, industry, agriculture, and aquaculture. tides), complex hydraulics.

- The scope and direction of effluent source impacts: Spreading in numerous directions is challenging to control. The sources along the Hau River and the Sea are easily drained; sources within the region (in the middle of the peninsula) are complex and irregular;

- The level of impact of wastewater sources: the further into the middle of the peninsula, the more complicated and polluted the sources become:

+ The impact of domestic wastewater on surface water quality in the study area is very clear, especially in the sections of rivers and canals flowing through urban areas, where the population density is high. significant decline;

+ Industrial wastewater is distributed with a relatively high volume concentration near discharge sources and then spreads very widely, affecting many areas on the peninsula;

+ Wastewater from agricultural fields only occurs in a small area in the middle of the peninsula, but it is likely to spread to Ca Mau and Kien Giang. Long-lasting, spreading throughout the region and its environs.

3.6 Orientation of technical measures to control wastewater sources

- For severely polluted regions, such as those between the peninsula and large cities (Can Tho, Soc Trang, Bac Lieu), it is necessary to prioritize the implementation of pollution-reduction measures. Surface water pollution (prevention of pollution at the

source and treatment of pollution at the end of the pipeline) is necessary to continue the objective of assuring sustainable socioeconomic development.

- For lightly polluted areas, consider large riverside areas (Hau River) and coastal areas (East and West Seas), as they have excellent water circulation, exchange, and drainage. easy. It is necessary to improve the capacity to self-clean contaminated water sources, to increase the drainage capacity by utilizing the tides (in coastal areas) and to maximize the quantity of water supplied from upstream via the Hau River.

This is the boundary between the two heavily polluted areas, so there will be a shift (not a fixed shift) in the polluted area due to the flow. It is necessary to adopt management measures with a focus on pollution prevention at the source and pollution treatment at the end of the pipeline.

CONCLUSIONS AND FURTHER STUDIES

I. Conclusion

The purpose of the thesis is to establish a scientific foundation for assessing the distribution of the major sources of effluent pollution (domestic, industrial, agricultural, and aquaculture) and elucidating the effects of these sources. wastewater to surface water quality in the Ca Mau Peninsula to provide orientations for technical measures to control wastewater sources (based on the scope of impacts of discharge sources) for the protection of natural resources. Surface water resources to satisfy the needs of the study area's sustainable socioeconomic development. The study has achieved the following main results:

- Regarding the study of waste discharge sources and wastewater loads affecting surface water quality in the Ca Mau Peninsula, the wastewater flow and refuse load of the study area (3,506,796 m3/day-night) in the province of Ca Mau have been calculated. has the highest volume of effluent discharged into rivers and canals (29.0%); Hau Giang has the lowest (8.5%). Since then, four major sources of wastewater affecting the water quality of the study area have been identified: domestic, industrial, crop and aquaculture waste, with crop wastewater (44.7%); aquaculture (33.3%); living (16%); and industry (5.2%) being the largest. Domestic wastewater is distributed throughout the peninsula (the greatest load accounts for 64.4%) along the region's rivers and canals (canal houses are also a characteristic feature of the study area). and concentrated in the region's cities; industrial waste sources are concentrated in large rivers such as Hau, Ganh Hao, and Ong Doc. Aquaculture waste sources are concentrated along the east and west coasts in the center of the peninsula. In particular, crop waste is concentrated (as a dispersed source) in the freshening areas of the northern and middle parts of the peninsula, making it difficult to regulate and affecting the region's surface water quality. Surface water in the BCC region has been contaminated with organic matter and microorganisms, with parameters exceeding the standards for DO, BOD5, NH4+, and total coliform (by 1.1 to 3.7 times the standard).

- The results of the study on the propagation of water sources in the Ca Mau Peninsula (Mike11-AD) indicate that the sources from the border of the Ca Mau Peninsula include those from the Hau River from upstream (the proportion of water composition accounts for more than 80%); from the East Sea and West Sea (more than 90 percent) are the dominant sources of hydraulic regime in the peninsula, so it also governs the dynamics of pollution sources. Domestic, industrial, agricultural, and aquaculture pollutants are the primary sources of

pollution within the peninsula. Infrequent waste sources, such as aquatic effluent and environmental incidents, have also contributed to the peninsula's environmental degradation.

- The results of the pollution dispersal simulation (MIKE-Ecolab) were used to assess the overall and specific surface water quality in the Ca Mau Peninsula. Severely polluted areas requiring immediate treatment measures have been identified, primarily in the cities of Can Tho, Soc Trang, and Ca Mau. The peninsula's central regions are severely polluted. Due to the influence of the tides of the East Sea and West Sea, there are areas bordering water where there is a limited exchange of water. The canals receive effluent from numerous sources, including the Ganh Hao River, Ca Mau - Bac Lieu canal, Quan Lo - Phung Hiep canal, and inner city canals. Large riverside areas (Hau River) and coastal areas (East and West Seas) are moderately polluted because they have excellent water exchange, easy circulation, and drainage.

- The study evaluated the effect of the discharge source on water quality and the influence of additional factors (tide, current). Because the majority of the rivers/canals of the study area are inhabited, domestic effluent is the primary source of influence on water quality in the Ca Mau Peninsula, exerting a very large scope and extent of influence. River/canal and domestic effluents that have not been treated are continuously discharged each hour into the water source. Additionally, industrial effluent has impacted the region. Although there are few sources, the high discharge volume has severely polluted some of the region's major rivers and canals. The remaining refuse sources (agriculture, aquaculture, etc.) are dispersed and difficult to control, negatively impacting the water quality of the study area.

Regarding the orientation of technical measures to control wastewater sources: with the discharge characteristics of various

categories of discharges in the Ca Mau Peninsula, primarily domestic, industrial, agricultural, and aquaculture wastewater. In addition to general management solutions to safeguard the surface water environment, it is necessary to prioritize the control of key waste sources in the study area as a top priority. At the same time, it is necessary to find a way to reuse effluent to prevent water waste and decrease pollution.

II. Future research

To better implement the results in practice and meet actual requirements, it is necessary to continue studying the following topics in greater depth:

- Additional research is required on the self-cleaning capacity of water sources in rivers and canals in the study area to aid in the management and control of pollution; distributed refuse sources (agriculture, stormwater runoff, etc.) are difficult to manage and require additional study.

- It is necessary to conduct additional research on the issue of transboundary water pollution to mitigate the effects of climate change on the surface water environment in the study area.

- Some typical discharge locations must be investigated in greater depth (simulation of water quality by a 3D model) to accurately determine the pollution rules and evolution in space (3D) to develop effective mitigation strategies.

LIST OF PUBLISHED RESEARCH PAPERS

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6. Nguyen Tung Phong, Ha Hai Duong, Nguyen Duc Phong, Water quality monitoring and management for domestic use and agriculture production in coastal irrigation systems in the Red river delta, Vietnam. Proceeding of the international conference on Science and Technology for water security disaster reduction and climate change adaptation. November 05, 2019. Science and Technics Publishing House, 2019. ISBN: 978-604-67-1627-3.