Science on Natural Resources and Environment
Journal homepage: tapchikhtnmt.hunre.edu.vn

ASSESSMENT OF THE BEARING CAPACITY OF THE MAIN RIVER SYSTEM IN NAM DINH PROVINCE

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Received 23 October 2023; Accepted 20 December 2023

Abstract

The process of urbanization and industrialization in Nam Dinh province's 10 districts and cities has led to many significant rivers being used for various purposes such as livestock farming, aquaculture, supplying water for clean water stations, and receiving wastewater, causing many river systems in the province to be altered, leading to the risk of imbalance and reduced self-purification and self-regeneration capacity of water sources in these rivers. This has increased the risk of water pollution and reduced the quality of surface water, resulting in a shortage of clean water for the daily lives of people in the province. The article has studied the application of the MIKE11-ECOLab model and correlation analysis method to assess the current situation of the wastewater receiving capacity of the central river system in Nam Dinh province. At the same time, it also analyzes and predicts the wastewater receiving capacity of the central river system in the province according to the trend of socio-economic development.

Keywords: MIKE11-ECOLab; Digital Elevation Model (DEM); Nam Dinh province.

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1. Introduction

The increase in population has put tremendous pressure on natural resources and the environment due to excessive exploitation of resources to serve human needs. The population growth creates large amounts of waste while also causing air and water pollution, especially in urban areas and craft villages; industrialization and urbanization also increase the quantity of waste and environmental pollution.

In recent years, due to the requirements of economic development, many industrial parks and clusters have been formed (Hoa Xa Industrial Park, My Trung Industrial Park, Bao Minh Industrial Park,...). These industrial parks and clusters have become operational, attracting many workers from various places and increasing the population in these areas (Nam Dinh city, My Loc, Vu Ban,...). The overcrowding has resulted in environmental pollution in urban areas, including air pollution caused by noise and dust from a high traffic volume, especially the increasing waste, and wastewater

from domestic and industrial activities, which puts tremendous pressure on the environment and directly affects the water source [2, 8].

The current situation of water resource management in Nam Dinh province shows that most wastewater comes from Nam Dinh city, towns, industrial clusters, and craft villages in the 10 districts and cities. They are discharged into rivers, canals, internal lakes, and urban areas and then flow into the four major rivers: the Hong River, Dao River, Day River, and Ninh Co river [6, 7].

The primary sources of water pollution are untreated or inadequately treated sewage from industrial production, craft villages, agricultural processing, domestic wastewater, and agricultural production. Suppose industrial wastewater, domestic wastewater, and livestock waste are treated after being discharged into ponds, lakes, fields, and rivers. In that case, it will harm aquaculture productivity. These industrial zones and craft villages have also created thousands of new jobs, contributing significantly to the economy, but water pollution has affected the lives of people and aquatic environments. Because there are very few craft villages with wastewater treatment systems, wastewater is mainly discharged directly into the general canal system or rivers, reducing surface water quality.

2. Data and research methods

The data used in this article was collected, surveyed, and sampled by the research team on the river water quality in Nam Dinh province. This data was investigated and observed in October 2018. In addition, there is also annual water quality monitoring data in 4 locations by the Nam Dinh Environmental Resources Monitoring and Analysis Center.

About flow data, the article uses the flows of 2007 and 2017 to simulate flood season flows. The flow from January 2009 to April 2009 and from January 2010 to April 2010 to affect the flow in the dry and flood seasons is the flood flow data in 2007 and 2017.

The sampling location map and information about sampling locations (Figure 1, Table 1) are as follows:

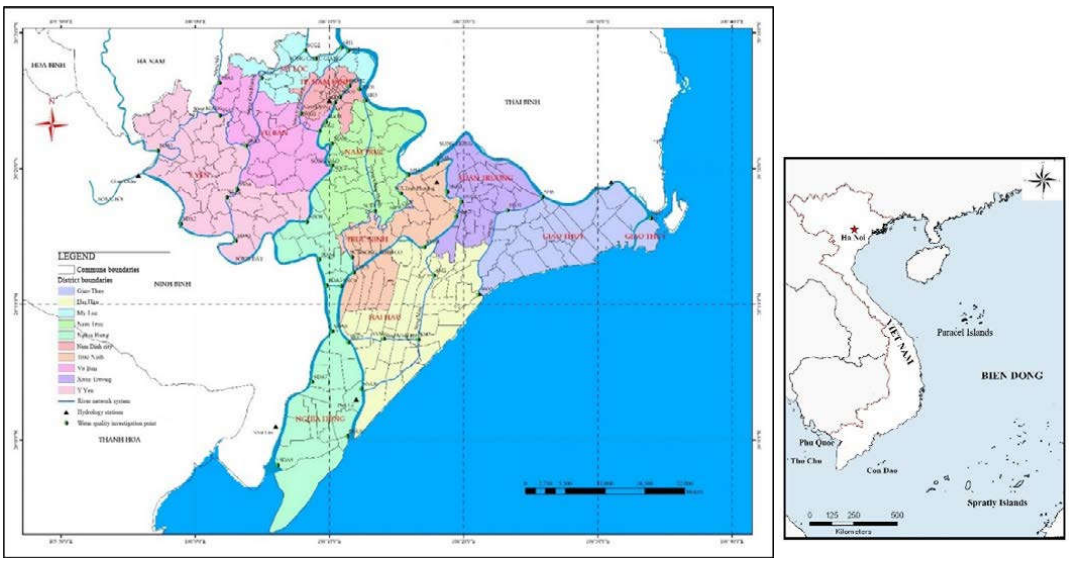


Figure 1: Map showing the locations of sampling points on the river system in Nam Dinh province

Table 1. Results of analyzing river water quality samples in Nam Dinh province

Order	Point	BOD	COD	N_NH_4	P_PO4	Turbidity	TSS	Coliform	DO	pH	Temperature
1	SDA1	10.5	24	0.16	0.18	43	298	5,300	7.20	7.30	30.50
2	SDA2	9.8	23	0.14	0.15	41	327	4,800	6.53	7.31	30.80
3	SDA3	9	22	0.12	0.17	44	267	4,200	6.70	7.28	30.40
4	SDA4	8.5	21	0.15	0.12	42	106	3,500	8.60	8.18	29.60
5	SDA5	9	22	0.17	0.14	43	109	3,700	8.40	7.26	29.40
6	SDA6	11	24	0.19	0.23	53	108	5,200	6.27	7.30	28.70
7	SDA7	18	30	0.27	0.16	60	109	8,500	9.00	7.50	28.30
8	SDA8	12	28	0.13	0.18	53	313	5,400	6.60	7.46	29.60
9	SNM	22.5	50	0.65	0.28	60	144	6,700	3.10	7.02	30.00
10	SM1	18	40	0.48	0.17	41	113	5,800	8.50	7.30	28.00
11	SM2	19.5	42	0.5	0.21	53	161	6,200	4.50	7.11	29.00
12	SCT1	19	45	0.46	0.25	58	198	6,200	6.47	7.56	32.50
13	SCT2	23.9	53	0.5	0.34	46	176	7,300	6.80	7.12	30.50
14	SCL	9.2	27	0.12	0.15	42	146	4,100	9.47	8.70	32.90
15	SNC1	9	20	0.18	0.08	41	101	3,400	8.20	7.20	32.00
16	SNC2	10.5	21	0.19	0.13	43	108	3,700	7.50	7.16	29.40
17	SNC3	12.3	23	0.21	0.21	40	100	4,300	6.80	7.18	29.80
18	SNC4	13	24	0.25	0.27	40	99	4,500	8.50	7.38	27.80
19	SNC5	8	22	0.23	0.24	32	134	6,200	8.50	7.42	27.90
20	SNC6	12	28	0.26	0.17	43	149	4,500	7.40	7.19	27.60
21	SNC7	14.5	35	0.31	0.25	58	181	5,300	6.20	7.12	28.40
22	SNC8	13.2	32	0.3	0.18	42	218	5,100	6.30	7.30	29.00
23	SNC9	12	30	0.28	0.17	38	684	4,600	6.90	7.23	29.80
24	SVG1	28	60	0.85	0.41	48	184	7,600	6.60	7.30	30.50
25	SVG2	12.4	28	0.23	0.27	40	114	6,100	6.07	7.52	29.60
26	SDO1-1	11	23.5	0.15	0.13	53	441	4,600	7.27	7.21	29.90
27	SDO1	11.5	25	0.17	0.18	73	208	5,100	6.73	7.22	29.10
28	SDO2	10.4	23	0.14	0.12	45	140	4,400	6.60	7.21	33.80
29	SDO3	9	21	0.13	0.14	48	175	4,200	6.27	7.22	28.80
30	SDO4	8.5	20	0.12	0.15	52	177	3,700	6.27	7.22	28.50
31	SDO5	9.2	22	0.14	0.13	54	174	4,300	6.40	7.23	29.70
32	SDO6	10.3	21	0.13	0.17	52	185	4,600	6.73	7.23	29.20
33	SDO7	8.7	20	0.12	0.15	50	202	3,500	6.73	7.27	29.80
34	SDO8	8	18	0.11	0.12	47	178	3,200	6.40	7.26	30.80
35	SSA1	21	45	0.41	0.32	48	343	6,400	7.63	7.32	30.30
36	SSA2	22.4	47	0.43	0.28	54	279	6,700	8.22	7.33	30.40
37	SSA3	18.5	43	0.42	0.21	51	272	6,100	8.87	7.27	33.20
38	SSA4	16.6	42	0.39	0.26	47	251	5,800	8.80	7.29	34.20
39	SSA5	15.7	42	0.36	0.18	50	247	5,800	8.00	7.28	33.80
40	SSA6	14.8	40	0.4	0.15	46	263	5,300	6.60	7.29	33.8
41	STH	30	70	1.35	0.45	56	173	8,700	9.47	8.50	327.00
42	SCG1	16.7	40	0.51	0.24	48	163	6,200	7.20	7.95	32.30

Order	Point	BOD	COD	N_NH_4	P_PO4	Turbidity	TSS	Coliform	DO	pH	Temperature
43	SCG2	18	42	0.53	0.27	40	168	6,700	7.53	7.37	32.10
44	SH1	11.5	26	0.16	0.15	53	120	5,400	6.80	7.10	30.10
45	SH2	13	28	0.18	0.22	45	99	5,800	7.80	6.90	29.10
46	SH3	10.1	24	0.13	0.09	43	99	4,200	8.10	7.10	29.50
47	SH4	9.5	22	0.1	0.12	42	98	4,100	8.20	6.98	29.80
48	SH5	8	18	0.09	0.07	32	101	2,800	7.30	7.19	28.40
49	SH6	9	20	0.12	0.09	41	99	3,200	8.80	7.20	28.70
50	SH7	10	23	0.13	0.12	43	103	4,250	7.83	7.08	29.27
51	SSO1	10	22	0.18	0.14	62	122	5,200	7.93	8.10	30.40
52	SSO2	11.5	24	0.21	0.18	41	276	5,700	5.60	7.05	28.50
53	SMD	16.45	35.5	0.295	0.23	48.5	288.5	6,000	6.34	7.32	30.45

The article uses the following two main methods in the research process:

- *Statistical method:* Used to analyze and evaluate the current state of the water environment of the main rivers in Nam Dinh province. After modeling, it is also used to interpolate data for profiles/cross-sections on the central river system.

- *Modeling method:* The article uses the MIKE11-ECOLab model to simulate the flow and water quality of the central river system.

3. Results and discussion

3.1. Partial basin and calibration of the MIKE11-ECOLab model

Using a 30 × 30 m Digital Elevation Model (DEM) map, a 1:10,000 topographic map, and a map of the administrative boundaries of communes, the report has divided the Nam Dinh province into 9 sub-basins.

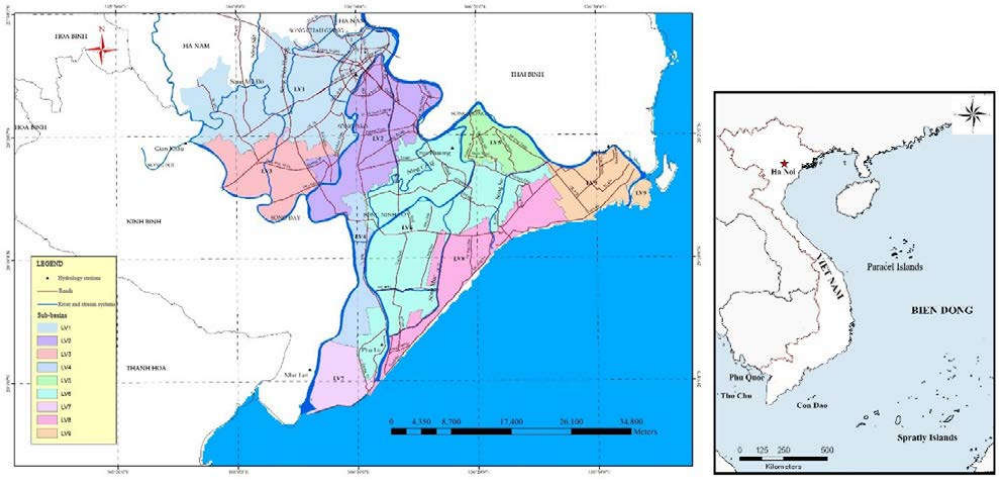


Figure 2: Sub-basins follow the main river system in Nam Dinh province

The ecology module (Ecolab) in the MIKE11 model comes with the AD module to address the biological transformation of compounds in the river, simulating the diffusion transport process of compounds.

The main parameters are adjusted using the trial and error method. The model's results are compared with the actual measurements at the intermediate station, with evaluation criteria such as Nash, total volume error, peak error,

and calculation process error, as well as the measurement of the computational factor; precisely, adjust the primary set of parameters by changing the coefficients up and down, then repeat the model run, and continue like that until the requirements are met. Data used to calibrate the flood season is 2007, and the dry season is 2009.

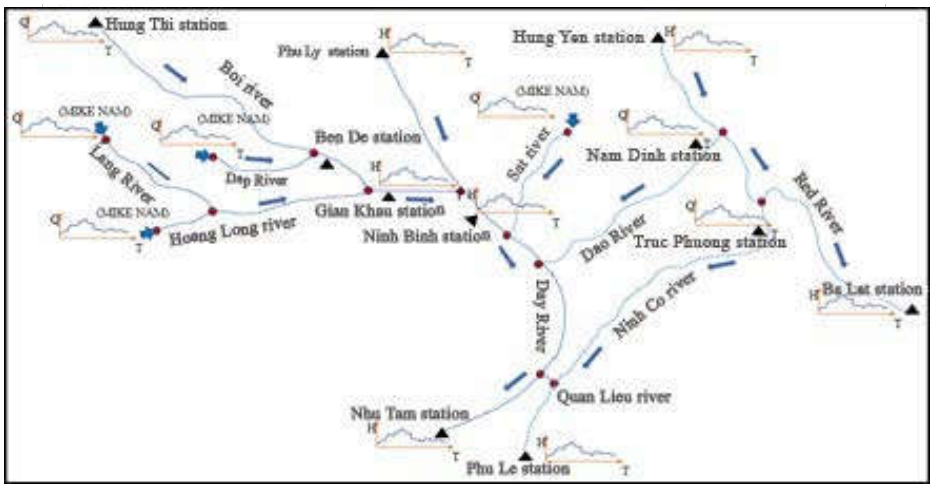


Figure 3: Hydraulic diagram and boundary conditions of the MIKE11-ECOLab model

Table 2. Evaluate simulation quality during the process Calibrate the MIKE11 model

Order	Targets	Flood in 2007		Dry season 2009	
		Gian Khau	Ninh Binh	Gian Khau	Ninh Binh
1	Nash	0.98	0.92	0.98	0.98
2	Total quantity error (%)	0.21	0.147	0.318	0.321
3	Error in base and peak values (m)	-0.064	0.039	-0.149	-0.173

The test used data from the dry season 2010 and the flood season 2017.

Table 3. Evaluate simulation quality during the process Testing the MIKE11 model

Order	Targets	Dry season 2010		Flood in 2017	
		Gian Khau	Ninh Binh	Gian Khau	Ninh Binh
1	Nash	0.94	0.88	0.97	0.95
2	Total quantity error (%)	-0.193	-0.229	0.063	0.119
3	Error in base and peak values (m)	0.515	0.616	0.145	0.139

3.2. Current status of water quality in Nam Dinh province

** For industrial wastewater*

According to the 2018 Report of Nam Dinh province water supply joint stock company, several production facilities have wastewater discharge exceeding 10 m^3/day. Among them, Hoa Xa Industrial Park has over 85 production units, 17 units belong to Bao Minh Industrial Park, and 4 units belong to My Trung Industrial Park. In addition, there are scattered production units in areas such as Nam Dinh city, Nam Truc, Vu Ban, and Y Yen,... The evaluation results of the current status of industrial wastewater discharge are as follows [2, 8, 9]: Industrial parks in Vu Ban, Nam Dinh city, a part of My Loc, have the highest discharge flow with 21,306 m^3/day, equivalent to the highest discharge rate (~ 136 m^3/day/km^2); the lowest is in Nghia Hung district with a discharge flow of 23 m^3/day, with a discharge rate of 0.30 m^3/day/km^2.

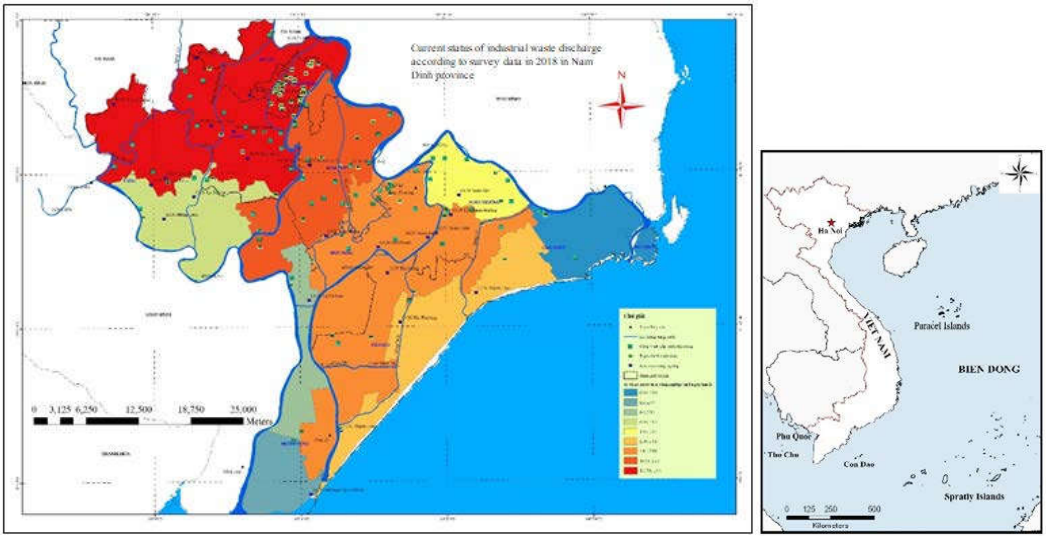


Figure 4: Current status map (2018) of industrial wastewater discharge in Nam Dinh province

** Regarding agricultural wastewater discharge, including livestock wastewater discharge, medical wastewater discharge, and educational wastewater discharge*

According to the Report of the Department of Agriculture and Rural Development of Nam Dinh province, document number 1647/CN-GSN of the Livestock Department, as of the end of 2017, there were 48 livestock production facilities in Nam Dinh province with wastewater discharge volume > 10 m^3/day. Among them were 12 duck farms, 9 chicken farms, 17 pig farms, 1 cattle farm, and 9 mixed farms. The assessment results of the current status of agricultural wastewater discharge are as follows [5, 9]: The highest discharge flow is 372 m^3/day, corresponding to the highest discharge rate of 2 m^3/day/km^2 occurring in the northwest of the province, mainly in Vu Ban, Y Yen and parts of the province - My Loc. The primary concentrated source of waste comes from poultry farms (Figure 5).

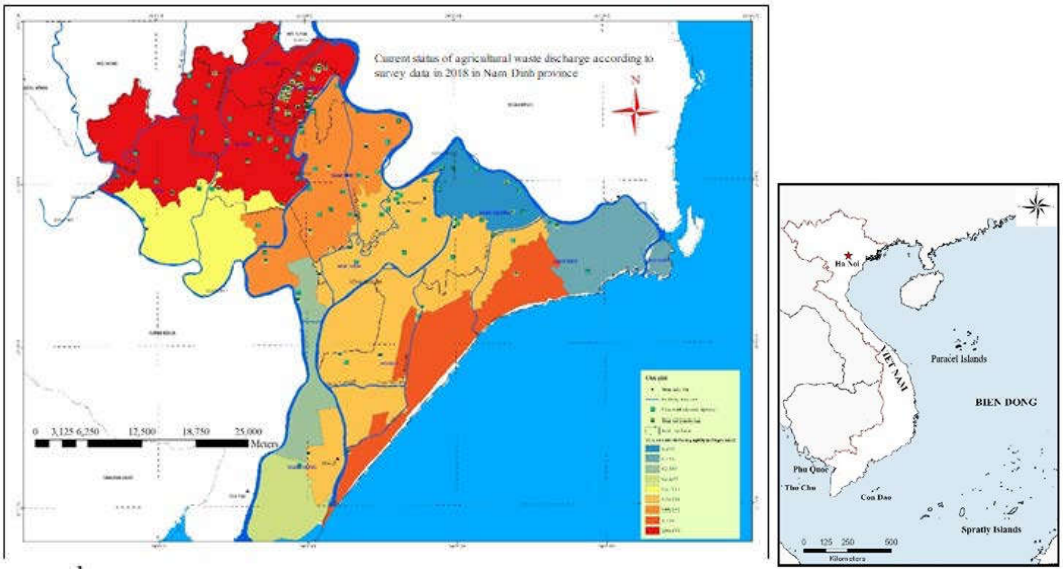


Figure 5: Current status map (2018) of agricultural wastewater discharge in Nam Dinh province

** Regarding discharge of domestic wastewater*

According to the 2020 Water Resources Planning Report of Nam Dinh province, with a vision towards 2030, there are 10 administrative units in Nam Dinh province, including 9 districts and Nam Dinh city. The total number of communes, towns, and wards in the province is 229, including 194 communes, 20 wards, and 15 towns. The average population density of the province is 1,116 people/km^2. The population is concentrated in urban areas and villages along essential transportation routes. The assessment results of the current status of domestic wastewater discharge are as follows [5, 9]: The highest discharge flow is 3,157 m^3/day, corresponding to the highest discharge rate of 20.21 m^3/day/km^2 also occurring in the northwest of the province, including Vu Ban, Y Yen, and My Yen districts, accounting for approximately 27.6 % of the province's waste discharge (Figure 6).

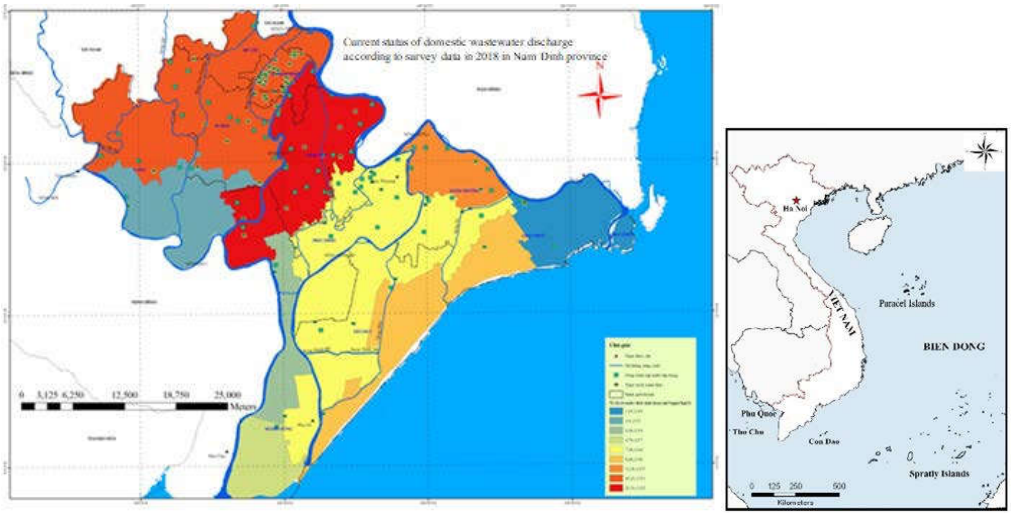
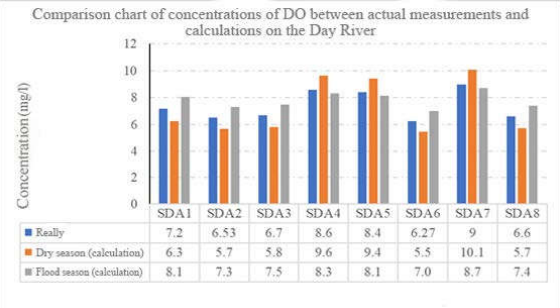


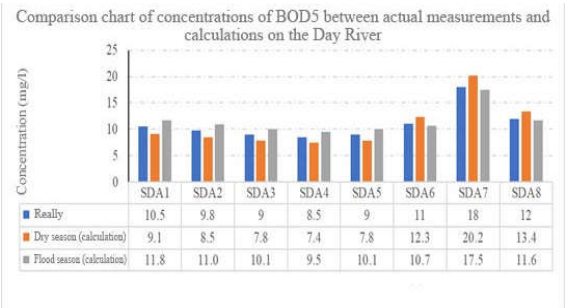
Figure 6: Current status map (2018) of domestic wastewater discharge in Nam Dinh province

3.3. Assessing the ability of the main river system to receive waste sources in Nam Dinh province

A report conducted a simulation of water quality during the dry and flood seasons to assess the capacity to receive wastewater from some main rivers in Nam Dinh province. The maximum concentrations of parameters including DO, BOD_5, $N\text{-}NH_4$, $P\text{-}PO_4$, and Coliform at specific locations along the Dao River, Sat River, Day River, Ninh Co river, and Hong River (part of Nam Dinh province) were statistically analyzed based on the survey locations and water quality sampling. The results are as follows:



	SDA1	SDA2	SDA3	SDA4	SDA5	SDA6	SDA7	SDA8
Really	7.2	6.53	6.7	8.6	8.4	6.27	9	6.6
Dry season (calculation)	6.3	5.7	5.8	9.6	9.4	5.5	10.1	5.7
Flood season (calculation)	8.1	7.3	7.5	8.3	8.1	7.0	8.7	7.4



	SDA1	SDA2	SDA3	SDA4	SDA5	SDA6	SDA7	SDA8
Really	10.5	9.8	9	8.5	9	11	18	12
Dry season (calculation)	9.1	8.5	7.8	7.4	7.8	12.3	20.2	13.4
Flood season (calculation)	11.8	11.0	10.1	9.5	10.1	10.7	17.5	11.6

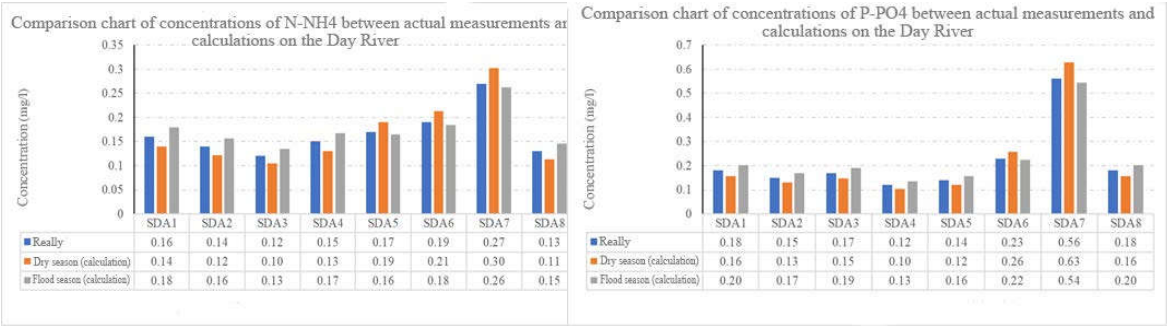


Figure 7: Comparison chart of concentrations of some indicators between actual measurements and calculations on the Day River: Really; Dry season (calculation); Flood season (calculation)

Based on the analysis and simulation results using the MIKE11-ECOLab model, the research group assesses the wastewater receiving capacity of water sources on several main rivers as follows:

On the Dao River, with 21 evaluation locations, the leading water quality concentration indices are within the A2 standard according to QCVN 08-MT:2015/BTNMT [1]. Therefore, the water source on the Dao River can still receive wastewater.

The leading water quality indices on the Sat River section in Nam Dinh province exceed the A2 standard according to QCVN 08-MT:2015/BTNMT, ranging from B1 to A2 standards. Preliminary results show that the Sat River can still receive additional wastewater.

On the Day River, with 72 evaluation locations, about 46 locations (accounting for 64%) have the leading water quality concentration indices within the A2 standard according to QCVN 08-MT:2015/BTNMT, and the remaining locations do not exceed the B1 standard. Therefore, the water source on the Day River can still receive wastewater.

On the Ninh Co river, with 54 evaluation locations, about 41 locations have all water quality indices exceeding the A2 standard but still within the B1 standard, while the remaining locations are within the A2 standard. This indicates that the Ninh Co river's water source can still receive wastewater.

On the Hong River (part of Nam Dinh province), with 48 evaluation locations, most locations have water quality indices within the A2 standard. Therefore, the water quality on the Hong River is still quite good, and there is still the ability to receive wastewater.

4. Conclusion

The assessment of the current status of wastewater discharge in Nam Dinh province has shown that the amount of concentrated wastewater is mainly found in the urban area of Nam Dinh city, some communes in Vu Ban, Nam Truc, and Truc Ninh districts. Most wastewater discharge comes from industrial activities, followed by domestic and educational wastewater. The discharge of agricultural and medical wastewater is negligible in Nam Dinh province.

Based on the analysis and evaluation, it is found that the water sources in the Dao and Hong rivers are still relatively good and capable of receiving wastewater. Although the water sources in the Sat, Day, and Ninh Co rivers exceed the A2 standard according to QCVN 08-

MT:2015/BTNMT, they can still receive wastewater with water quality that meets the A standard according to QCVN40-2011-BTNMT.

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