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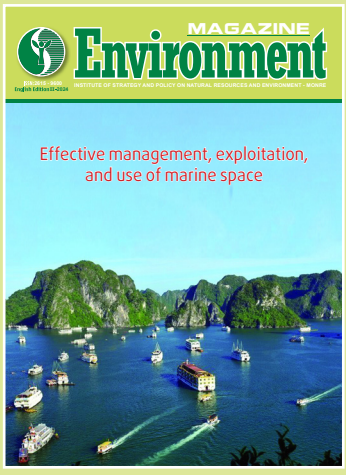

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CONTENTS

RESEARCH

FORUM - POLICY

AROUND THE WORLD

POLICY - PRACTICE

The efficiency of pretreatment using thermal hydrolysis method with alkali dilution for bioethanol production from rubber wood sawdust

NGÔ TRẦN BẢO VIỆT[1,2], HUỲNH NGUYỄN ĐỨC TÀI[1,2], TRẦN THANH TOÀN[1,2], LÊ NGUYỄN PHÚC THIÊN[1,2], NGUYỄN ĐÌNH QUÂN[1, 2, *]

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Abstract

The research on producing bioethanol from this rubber wood sawdust waste provides a method for generating green fuel from a cheap, abundant, and currently wasted resource. With the aim of improving the conversion efficiency of bioethanol from rubber wood sawdust, this study combined alkali dilute pretreatment with high pressure to facilitate easier hydrolysis of rubber wood sawdust and fermentation with Saccharomyces cerevisiae. In the study, HPLC and UV-Vis methods were used to determine the composition and content of lignin, cellulose of the raw material before and after pretreatment. Additionally, Saccharomyces cerevisiae yeast was cultured in Sabouraud dextrose Broth (SDB) medium to achieve high cell density prior to use. Simultaneous saccharification and fermentation (SSF) were conducted with appropriate temperature, time, and conditions to optimize the conversion efficiency of cellulose, hemicellulose into ethanol. The pretreatment conditions were optimized for sawdust by soaking in 2% NaOH solution for 24 hours, followed by pretreatment in a high-pressure device at 170°C (7,02 bar) for 1 hour. The results showed that sawdust after pretreatment had an increased cellulose content from 43.20% to 66.63%, with a pretreatment efficiency of 70.53%. The material subjected to pretreatment was proven to be advantageous for the fermentation process, with the resulting solution having bioethanol content of 1.68% vol and a conversion efficiency of 60.32% for the entire process.

Keywords: *Bioethanol, Pretreatment, High Pressure, Saccharomyces cerevisiae, Lignocellulose.*

JEL Classification: *Q50, Q55, Q57.*

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1. INTRODUCTION

The research on the bioethanol production process from lignocellulosic biomass has been carried out for decades [2][3]. However, in Vietnam, many studies on bioethanol still face challenges when transitioning to using lignocellulosic feedstock (second generation) due to various hurdles, such as issues with hydrolysis and the presence of lignin hindering enzymatic hydrolysis processes. Therefore, in the production of bioethanol from lignocellulose, the pretreatment stage is indispensable for lignin removal, improving the cellulose structure of the raw material, and creating favorable conditions for enzymatic hydrolysis. this study investigates the combined effectiveness of high-pressure conditions with diluted alkali in the pretreatment process applied to rubber wood sawdust feedstock. This research explores suitable conditions for the pretreatment process using the combined method to enhance the overall efficiency of bioethanol production.

The production of bioethanol from lignocellulosic biomass (second generation) is intensively researched due to its sustainability and abundant raw material, contributing to energy security and climate change mitigation. However, in Vietnam, transitioning to using lignocellulosic feedstock in bioethanol production faces challenges due to hydrolysis issues and lignin interference. This necessitates an efficient pretreatment stage to remove lignin, improve cellulose structure, and create favorable conditions for enzymatic hydrolysis.

This study focuses on evaluating the impact of various conditions, including concentration, treatment time with NaOH, temperature, and pressure on the cellulose structure of rubber wood sawdust. This is a crucial issue to optimize the pretreatment process, enhance bioethanol production efficiency from second-generation feedstock in Vietnam, and promote research in this field. The specific goal is to assess the effects of alkali solutions, pretreatment time, and temperature on the cellulose structure of rubber wood sawdust through parameters such as crystallinity index, porous structure, and amorphous cellulose regions, aiming to find the most suitable pretreatment method.

2. MATERIALS AND METHODS

2.1. Materials and chemicals

Rubber trees are perennial crops widely cultivated, with a large cultivation area in Vietnam ranking second in ASEAN and fifth globally in rubber cultivation. Every year, the rubber industry produces about 1.5 million tons of natural rubber. Following a growth cycle of 6-8 years, rubber latex is harvested. After harvesting, much of this wood is used for paper production, leaving behind rubber wood sawdust, estimated to reach millions of tons annually. This is a rich source of raw material that can meet research and application demands.

Rubber wood sawdust offers several advantages compared to other types of wood such as pine, oak, or beech. Specifically, it contains higher cellulose content (rubber wood sawdust has about 45-50% cellulose, while pine only has 40-43%, and oak ranges from 35-40%) and lower lignin content (rubber wood sawdust about 10%, while pine has around 27%, and beech about 23%). This creates favorable conditions for hydrolysis and fermentation into bioethanol [13][14].

In this experiment, the used lignocellulosic material is rubber wood sawdust from Binh Duong province, Vietnam. The sawdust, sourced from Minh Phat One Member Co., Ltd, is mechanically processed and sieved to a size smaller than 1mm, then dried and stored below 15% moisture content. Before determining the lignocellulose composition, the material is dried at 110°C until a constant weight is achieved.

Several chemicals used in the research include sodium hydroxide, potassium sodium tartrate tetrahydrate, glucose, peptone, and yeast extract (for yeast fermentation), sourced from Xilong. Saccharomyces cerevisiae, Ethanol ReD TM, is provided by the biofuel and biomass laboratory.

2.2. Analysis of composition and structure of raw materials

The composition of rubber wood sawdust is analyzed following the National Renewable Energy Laboratory (NREL) laboratory analysis procedure [8]. The sawdust is first hydrolyzed with concentrated sulfuric acid (72% w/w) for 30 minutes, followed by dilution with distilled water for a second hydrolysis step with diluted acid (4.0% w/w). The cellulose and hemicellulose components hydrolyze into glucose and xylose, respectively, and are analyzed using High-Performance Liquid Chromatography (HPLC) with a Shimadzu CTO-20A HPLC system and SUGAR SH101 column (Shimadzu HPLC analyzer, 2014). The lignin content is determined using a UV-Vis analysis instrument, specifically the NiR V770 model (Japan).

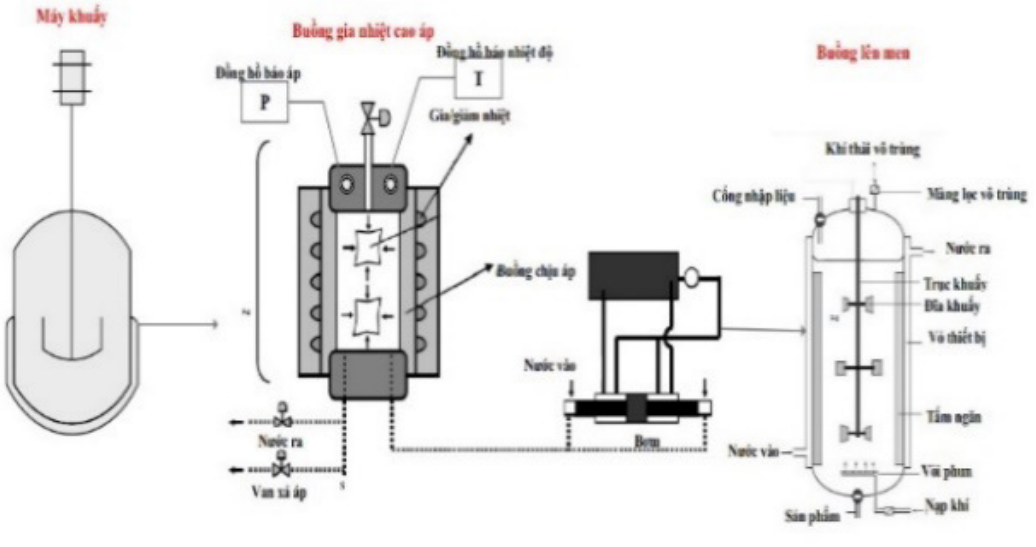
2.3. Dilute alkali pretreatment combined with high pressure investigation

The rubber wood sawdust pretreatment process was divided into two stages. In stage 1, 20g of sawdust was placed in a stirring vessel, followed by the addition of NaOH at various ratios and stirred at 120 rpm for different durations as investigated. Subsequently, the mixture was transferred to a high-pressure device for heating and pressure increase.

The experimental conditions were summarized in Table 1.

After the pretreatment process was completed, the sawdust was washed and adjusted to pH=7. Then, the fiber composition of the pretreatment-treated rubber wood sawdust was analyzed.

The pretreatment efficiency depended on the amount of cellulose enriched per unit of lignin and disregarded other components. This



▲ *Figure 1. Schematic diagram of rubber wood sawdust pretreatment using NaOH enhanced high-pressure method*

process primarily removed lignin and has little or no effect on other remaining components. The efficiency of the pretreatment process was calculated using Equation (1).

$$H_1(\%) = 100(\%).\left(1 - \frac{Y_2}{Y_1}\right) \quad (1)$$

Where Y1 and Y2 represented the mass ratio of lignin/cellulose of the material before and after the pretreatment process, respectively.

2.4. Preparing yeast and culture medium

Before fermentation, the Saccharomyces cerevisiae yeast strain Ethanol ReD TM was activated in Sabouraud dextrose Broth (SDB) liquid medium, sterilized at 121°C for 10 minutes. The yeast inoculation process took place in a shaking incubator (120 rpm, 35°C, for 48 hours). The yeast density was measured using optical density (OD) at a wavelength of 610nm using a UV-Vis Hach DR 5000 device.

2.5. Simultaneous Enzymatic Hydrolysis and Fermentation

The rubber wood sawdust after treatment was loaded into a 250 mL Erlenmeyer flask, supplemented with water at a solid/liquid ratio of 1/10 and 2.0% peptone. The mixture was then heated to 121°C for 10 minutes and cooled down to 35°C. Subsequently, 5.0% vol of Saccharomyces cerevisiae yeast and 5.0%vol of Acremonium Cellulase enzyme (from Meiji Seika) with an activity of 100 IU/mL are added. The fermentation medium was maintained in a shaking incubator at 35°C and 120 rpm throughout the Simultaneous Saccharification and Fermentation (SSF) process. The reaction flasks were tightly sealed to prevent CO_2 from escaping and to prevent contamination of the fermentation medium by other microorganisms.

The ethanol conversion efficiency was calculated based on the theoretical amount of ethanol converted from the cellulose of the initial rubber wood ([EtOH]* was 2.785% volume ethanol in this study) using the following equation (2):

$$The\ ethanol\ coversion\ efficiency = \frac{[EtOH]}{[EtOH]^*}\ 100\,(\%) \quad (2)$$

Where [EtOH] was the maximum concentration of ethanol producedduring the fermentation process(volume).

3. RESULTS AND DISCUSSIONS

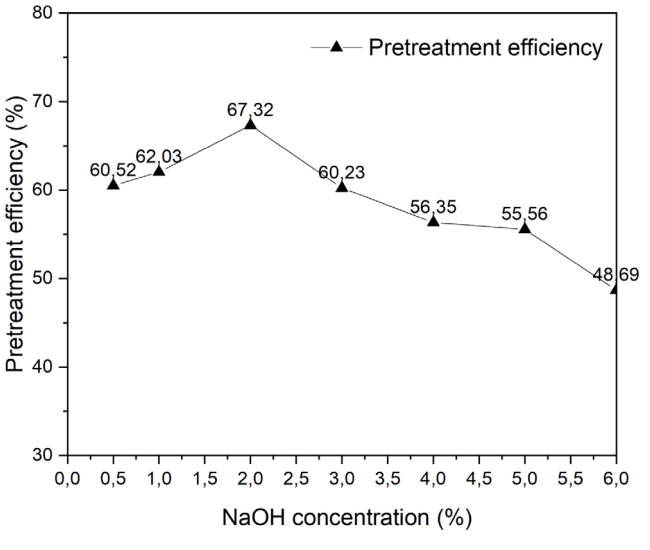
3.1. Results of raw material composition and structure analysis

The analysis results show that the main components include cellulose (43.20%), hemicellulose (21.22%), lignin (20.56%), ash (3.42%), and other components (11.63%). The high cellulose content indicates the potential for converting rubber wood into bioethanol. From the component results, the lignin/cellulose ratio can be calculated as 0.48. This ratio indicates that the lignin content in rubber wood is significant, almost half of the cellulose content. It is necessary to remove lignin before proceeding with hydrolysis and ethanol fermentation.

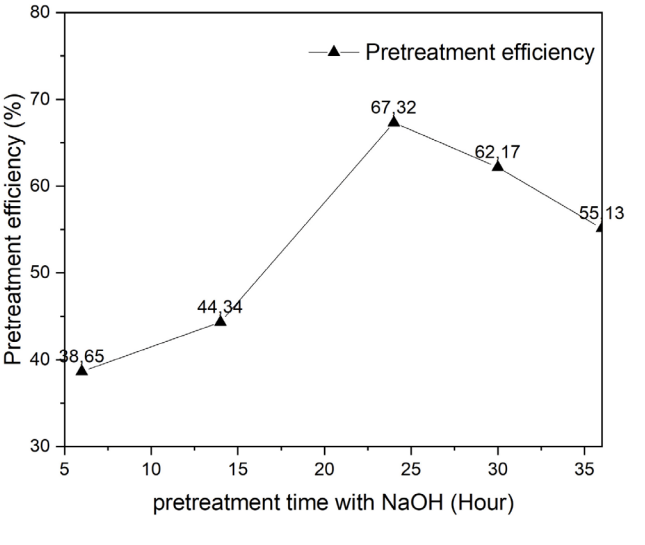
3.2. Investigation of concentration and time in stage 1: NaOH pretreatment

This study has provided new insights into the influence of NaOH concentration and time in the alkali pretreatment process on the efficiency of pretreatment for rubber wood sawdust.

From the results in Figure 2 and Table 1, it can be observed that the effect of



▲ *Figure 2. Experimental investigation of the influence of NaOH concentration inthe pretreatment process*



▲ *Figure 3. Experimental investigation of the influence of NaOH pretreatment time*

Table 1. Experimental conditions and component analysis results

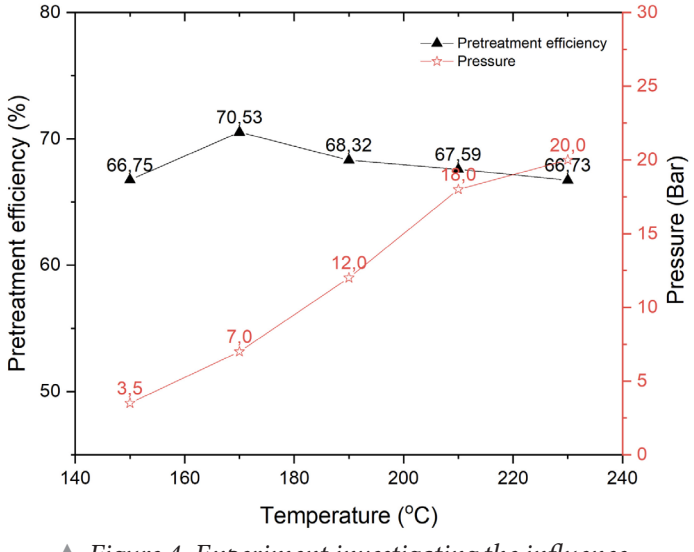
The univariate effects	NaOH concentration (%)	Chemical pretreatment time (h)	High-pressure temperature(°C)	High-pressure time (h)	Pressure (bar)	Cellulose	Hemicellulose	Lignin	Ash	Remaining substances	Y2: Lignin/ cellulose
NaOH concentration	0,5	24	150	1	3,45	55,86	14,52	10,50	4,07	15,06	0,188
	1	24	150	1	3,43	56,47	14,12	10,20	5,03	14,18	0,181
	2,0	24	150	1	3,38	61,40	15,35	9,55	4,30	9,40	0,156
	3,0	24	150	1	3,45	50,32	12,58	9,52	3,52	24,05	0,189
	4,0	24	150	1	3,48	46,52	11,63	9,67	3,26	28,92	0,208
	5,0	24	150	1	3,49	44,95	11,24	9,51	6,74	27,56	0,212
	6,0	24	150	1	3,54	39,17	9,79	9,57	8,62	32,85	0,244
Chemical pretreatment time	2	6	150	1	3,59	49,07	12,27	14,33	5,89	18,45	0,292
	2	14	150	1	3,46	45,19	11,30	11,97	5,42	26,12	0,265
	2	24	150	1	3,38	61,40	15,35	9,55	4,30	9,40	0,156
	2	30	150	1	3,42	59,03	14,76	10,63	6,13	9,46	0,180
	2	36	150	1	3,51	44,85	11,21	9,58	6,73	27,63	0,214
High-pressure temperature	2	24	150	1	3,39	60,38	15,10	9,55	4,23	10,74	0,158
	2	24	170	1	7,02	66,63	14,66	9,35	4,66	4,70	0,140
	2	24	190	1	12,22	63,38	14,58	9,56	4,44	8,05	0,151
	2	24	210	1	17,83	61,91	12,38	9,55	4,33	11,82	0,154
	2	24	230	1	19,87	60,34	9,05	9,55	4,22	16,83	0,158
High-pressure time	2	24	170	0,5	7,09	60,76	15,19	9,55		10,24	0,157
	2	24	170	1	7,02	66,63	14,66	9,35		4,70	0,140
	2	24	170	2	7,03	65,08	16,27	9,56		4,54	0,147
	2	24	170	3	7,06	63,40	15,85	9,56		6,74	0,151
	2	24	170	4	7,06	62,73	15,68	9,56		7,63	0,152

NaOH concentration shows an increase in pretreatment efficiency from 60.56% to 67.32% when increasing the concentration from 0.5% to 2%. This is because NaOH has a stronger effect in lignin removal and reducing the crystallinity of cellulose. However, when the NaOH concentration is further increased to 6%, the pretreatment efficiency decreases to 48.69%. This could be due to the high NaOH concentration causing significant loss of carbohydrates, leading to the loss of small cellulose and hemicellulose fibers during processing and washing.

The results regarding excessively high NaOH concentrations leading to carbohydrate loss align well with the findings from reference [9], which suggest that lignin removal using alkali can reduce efficiency due to the loss of cellulose and hemicellulose fibers.

Additionally, previous studies have also indicated that overly strong pretreatment conditions such as high temperature, high alkali concentrations, or prolonged processing times can lead to significant losses in valuable carbohydrate components in the feedstock [10]. Therefore, it is necessary to optimize the pretreatment conditions to achieve the highest efficiency possible.

In summary, this study has provided new data on optimal conditions (2% NaOH concentration, 24-hour duration) for alkali pretreatment of rubber wood sawdust. These conditions align with previous theories and research results indicating the importance of avoiding overly strong pretreatment conditions to minimize carbohydrate losses.



▲ *Figure 4. Experiment investigating the influence of high-pressure temperature on the efficiency of high-pressure pretreatment*

3.3. Study the temperature and time conditions for stage 2: High-pressure pretreatment

To enhance the efficiency of the process, this study has introduced a novel finding regarding the application of high-pressure methods to improve the efficiency of alkali pretreatment of rubber wood sawdust for bioethanol production. The results indicate that combining soaking the raw material in a 2% NaOH solution for 24 hours (stage 1) and subsequently conducting pretreatment at 170°C and 7.02 bar pressure for 1 hour (stage 2) resulted in the highest pretreatment efficiency of 70.53%.

The results from Figure 4 show that increasing the temperature and pressure to certain levels (170°C, 7.02 bar) enhances the pretreatment efficiency by promoting molecular oscillation and increasing lignin solubility. However, when the temperature and pressure are too high (230°C, ~20 bar), the efficiency decreases due to increased thermal hydrolysis of hemicellulose, cellulose, and lignin degradation.

The optimal high-pressure pretreatment time recorded in this study is 1 hour, as longer times reduce efficiency and consume more energy.

The use of NaOH as an alkali treatment agent in stage 1 aligns with previous studies suggesting that alkalis can remove lignin and enhance enzyme access to cellulose [4][5].

Furthermore, the concept of combining alkali soaking with increased temperature and pressure to enhance pretreatment efficiency has also been applied in other studies on different lignocellulosic materials. For example, Kumar et al. (2009) [11] studied straw, and Allan Zhong (2016) [12] researched rubber wood.

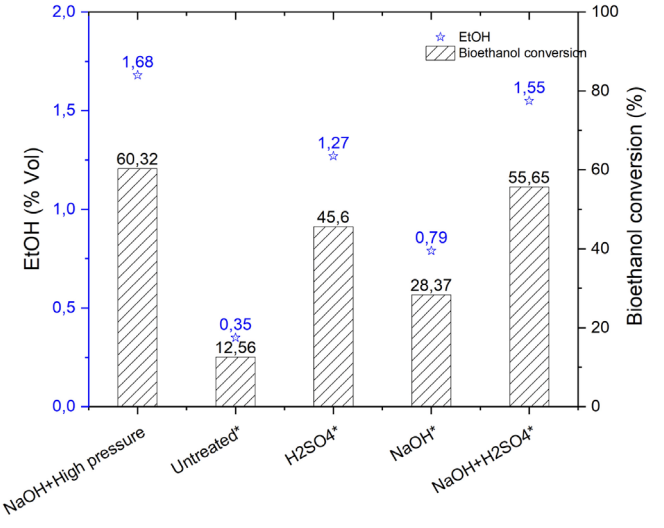
3.4. Evaluation of simultaneous saccharification and fermentation process (SSF)

The results demonstrate that enhancing high-pressure conditions for the alkali pretreatment process with NaOH (as described in Sections 3.2 and 3.3) yielded the highest ethanol yield of 1.67% vol with a bioethanol conversion rate of 60.32%. The improved pretreatment efficiency increased the enzymatic hydrolysis efficiency by increasing cellulose content and significantly reducing lignin content. The reduction in lignin content enhanced the enzymatic hydrolysis efficiency.

Comparing these results with the fermentation of rubber wood sawdust from the study by Le Tan Nhan Tu et al. (2020), where treatment with only acid yielded 0.79% vol ethanol and treatment with only alkali yielded 1.27% vol, with bioethanol conversion rates of 28.51% and 45.62%, respectively. The combined acid-alkali approach also resulted in an ethanol concentration of only 1.55% vol (with an efficiency of 55.65%) [10].

These findings highlight the significant importance of enhancing high-pressure conditions for the alkali pretreatment process with NaOH to promote enzymatic hydrolysis and simultaneous saccharification and fermentation (SSF) by rapidly removing a substantial amount of lignin and loosening the structure of rubber wood sawdust.

4. CONCLUSION



▲ *Figure 5. SSF fermentation results of TXL samples with different methods (Results from the experiment by Le Tan Nhan Tu and colleagues (2020) [10]).*

This study has highlighted the importance of the pretreatment step in the conversion process of rubber wood sawdust into bioethanol and the effectiveness of applying high-pressure methods to enhance the pretreatment process. The optimal conditions consist of two stages: (1) Soaking the raw material in 2% NaOH for 24 hours and (2) Pretreatment at 170°C and 7.02 bar for 1 hour, achieving the highest efficiency of 70.53%. These results outperform previous pretreatment methods, demonstrating the positive impact of combining alkali soaking with increased temperature and pressure.

Despite achieving high efficiency, the study still faces certain limitations. The use of high-pressure conditions requires specialized equipment and higher energy costs compared to conventional methods. Building upon this research, future studies can focus on optimizing the entire bioethanol production process from rubber wood sawdust, combining optimal pretreatment conditions with other factors such as selecting yeast strains, fermentation conditions, etc. Additionally, further research on the application of high-pressure methods for pretreatment of other lignocellulosic materials is also a worthwhile direction.This research could

provide a quality solution for the bioethanol production industry in Vietnam, promoting sustainable energy and contributing to environmental pollution reduction and energy security in the country.

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1.INTRODUCTION

Cua Lo sea area (Nghe An) has relatively flat terrain and a long coastline creating tourist beaches that are one of the beautiful beaches of Vietnam. Besides, there are many islands and peninsulas that create wonderful landscapes, create outstanding economic development, and at the same time serve as a premise for important research on biodiversity and ecology to find ecotourism solutions and environmental protection. Cua Lo beach area is surrounded to the north by Lan Chau island and Lam River to the south. On the other hand, in Cua Lo waters, Lan Chau Island is located close to the coast; 4km from the shore is Hon Ngu Island. These two islands have different ecosystems in both area and habitat, so there are differences in the distribution of coastal benthic animals. Lan Chau island is located right next to the coast (also known as Ru Coc), the island's foot sinks below sea level at high tide, the west of the island connects to the mainland into a peninsula at low tide, to the east are steep cliffs stretching towards the sea. Hon Ngu Island consists of 2 islands, large and small, with an area of only 2.5 km², has a more diverse ecosystem and is home to many benthic species.

Species composition and distribution characteristics of zoobenthos in Cua Lo coastal area, Nghe An Province

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Abstract

Due to survey data on benthic species composition in Cua Lo coastal area is limited, the article provides data on species composition, differences and distribution levels of benthic animals in coastal and island areas as well as contributing to completing research on benthic diversity and proposing management and conservation of biodiversity in the coastal area of Cua Lo (Nghe An) in particular and Vietnam in general. The research applies sampling methods in Cua Lo coastal area (Nghe An): Field research methods (collection methods, animal fixation and storage methods) and laboratory research methods (determination of nomenclature of types and data processing methods). Results of analysis of research samples have identified 86 species belonging to 3 main groups (Bivalvia, Crustacea and Grastropoda). Crustaceans have the highest number of species with 33 species, followed by gastropods with 29 species and bivalve molluscs with the lowest number of species with 24 species. 5 species with only identified genera should be kept as sp. (Grapsus sp.; Neoliomera sp.; Alia sp.; Olivella sp. and Gibbula sp.).

Keywords: *Nghe An, Zoobenthos, Gastropoda, Crustacea, Bivalvia.*
JEL Classifications: *P48, Q56, Q57.*
Received: *19th February 2024*; **Revised:** *11th March 2024*; **Accepted:** *25th May 2024.*

Benthic animals in the sea have certain economic significance; many groups have been identified as having an important daily food role for coastal residents and export value such as shrimp, crabs, fiddler crabs, snails. The coastal area of Cua Lo is exploited by humans without planning and without management measures, leading to benthic resources at risk of ecological imbalance. With the important role of benthos, there have been studies relating to benthic species in the surrounding area such as: (H.N. Khac, 2021) Assessing the crab species composition in the mangrove ecosystem (Thanh Hoa), (N.T. Binh, 2022). Research on species composition and distribution of benthic animals in Vung Ang waters (Ha Tinh). Currently, in the coastal area of Cua Lo (Nghe An), there is no research data on benthic groups in this area.

Survey data on benthic species composition in Cua Lo coastal area is still limited. Therefore, this article provides data on species composition, differences and distribution levels of benthic animals in coastal and off-island areas. At the same time, it contributes to completing research on benthic diversity and proposes management and conservation of biodiversity in the coastal area of Cua Lo (Nghe An) in particular and Vietnam in general.

2. METHODS AND MATERIALS

***Time*:** Qualitative and quantitative samples were collected in June - July 2023 in the coastal area of Cua Lo (Nghe An). Sampling points are identified, numbered and recorded (Figure 1).

Research subjects: Subjects are all species belonging to 3 groups of benthic animals (Crustacea, Gastropoda and Bivalvia).

Field research methods:

- *Sampling method:* Samples were collected from the bottom, tidal flats, substrates, including spaces above trees and deep in the bottom until all benthic animals were gone. For tidal areas, use a triangular rake with a 1mm mesh size (25 x 25cm) and drag the rake across the bottom to collect benthic animals. Samples were collected from all groups of crustaceans, gastropods and bivalve molluscs until no longer found. The location of sampling points is determined by coordinates.

- *Sample fixation and preservation:* After washing, the sample was fixed in 70° alcohol. Samples are distinguished from each other by numbered labels, clearly stating the location and location of sampling, then brought back to the laboratory for analysis.

Laboratory research methods:

- Determine species nomenclature: In the process of classifying 3 groups of benthic animals (Crustaceans, Gastropoda and Bivalvia) based on the morphological characteristics of the outer shell according to descriptive documents such as:

+ Crab group (Brachyura): According to the legal identification of crab species (Dai and Yang, 1994), (Crane, 1975);

+ Bivalvia and Gastropoda): Determined according to species nomenclature (Kent and Volker, 1998); (Han and Jap, 2006);

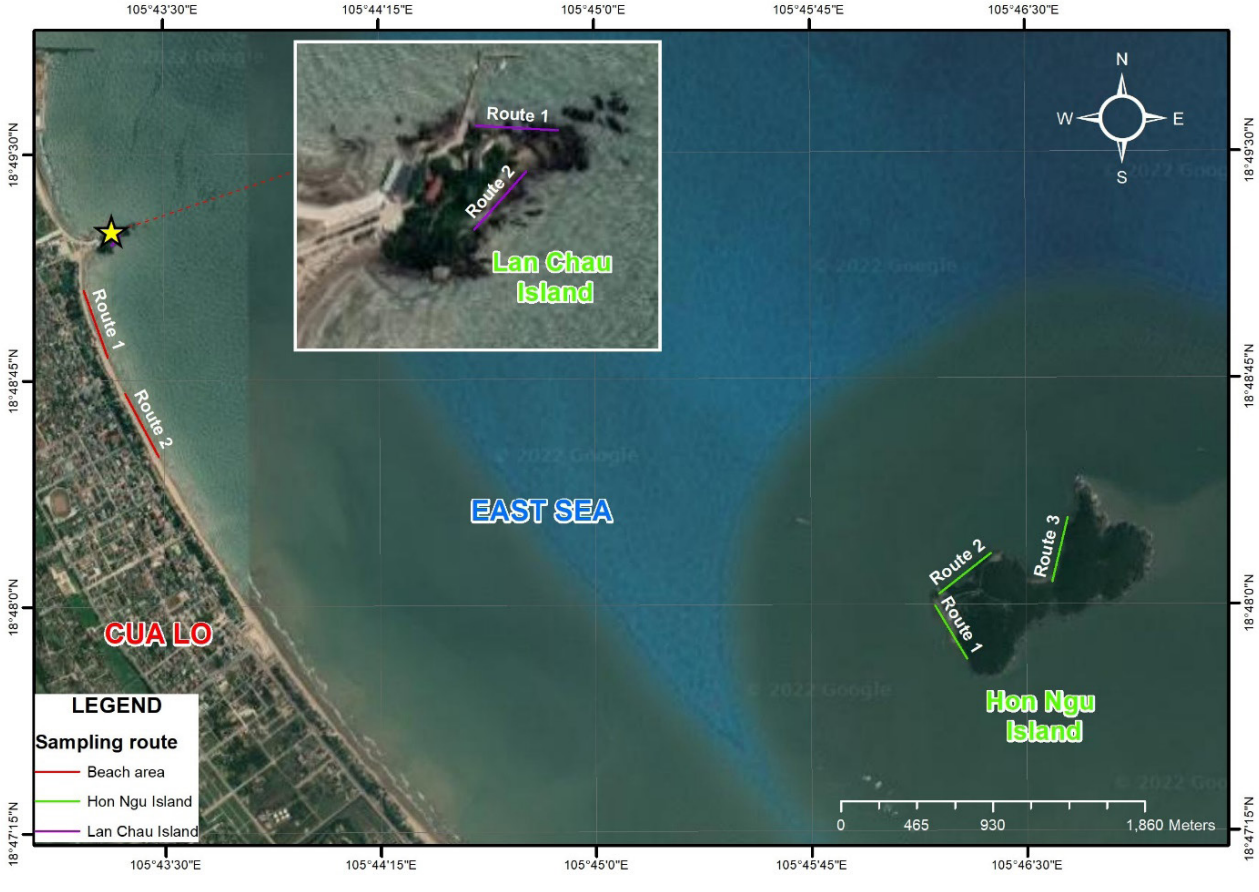
- Data processing methods: Data in the study were processed using Microsoft Excel 2010 software. Maps were processed and drawn using Map Info software 15.0.

All samples after analysis are separated by species, counted and stored at the laboratory of the Vietnam Environmental and Marine Science Institute.

3. RESULTS AND DISCUSSIONS

3.1. Benthic fauna composition

Research results on benthic species composition collected in the coastal area of Cua Lo, Nghe An province have identified 86 species, belonging to 66 genera, 45 families and 18 orders belonging to 3 main groups (Bivalvia, Crustacea and Grastropoda). Among them, the Veneridae family is the most diverse with 7 species (accounting for 8.14% of the total number of species), the two families Arcidae and Portunidae have 6 species (accounting for 6.98% of the total number of species). The remaining families have a small number of species, less than 5 species. The species has not been identified, only the genus of 5 species has been identified *(Grapsus sp.; Neoliomera sp.; Alia sp.; Olivella sp. and Gibbula sp.)*.



▲ *Figure 1. Sampling routes in the coastal area of Cua Lo (Nghe An)*

Table 1: Composition of benthic fauna in Cua Lo coastal area

No.	Taxon	Allocation		
		Coastwise	Lan Chau Island	Hon Ngu Island
	Arthropoda			
	Crustacea			
	Penaeidae			
1	Metapenaeus ensis (De Haan, 1844)	x		
2	Mierspenaeopsis hardwickii (Miers, 1878)	x		
3	Parapenaeopsis sculptilis (Heller, 1862)	x		
4	Penaeus indicus (H.Milne - Edwards, 1837)	x		
5	Penaeus monodon (Fabricius, 1798)	x		
	Sergestidae			
6	Acetes japonicus Kishinouye, 1905	x		
	Porcellanidae			
7	Petrolisthes armatus (Gibbes, 1850)		x	
	Diogenidae			
8	Diogenes mixtus Lanchester, 1902		x	
9	Diogenes violaceus Henderson, 1893		x	x
	Alpheidae			
10	Alpheus dispar Randall, 1840	x		
	Palaemonidae			
11	Nematopalaemon tenuipes (Henderson, 1893)	x		
12	Macrobrachium equidens (Dana, 1852)	x		
	Dorippidae			
13	Paradorippe granulata (De Haan, 1841			
	Euryplacidae			
14	Eucrate crenata (De Haan, 1835)	x		
	Grapsidae			
15	Grapsus tenuicrustatus (Herbst, 1783)		x	x
16	Grapsus sp.			x
	Leucosiidae			
17	Leucosia anatum (Herbst,1783)	x		
18	Lyphira heterograna Ortmann, 1892	x		
	Matutidae			
19	Ashtoret lunaris (Forskål, 1775)	x		
	Portunidae			
20	Charybdis anisodon (De Haan, 1850)	x		
21	Charybdis callianassa (Herbst, 1789)	x		
22	Charybdis feriatus (Linnaeus, 1758)	x		
23	Portunus sanguinolentus (Herbst, 1783)	x		
24	Portunus pelagicus (Linnaeus, 1766)	x		
25	Portunus trituberculatus Rathbun, 1902	x		
	Sesarmidae			
26	Parasesarma bidens (De Haan, 1835)		x	x
27	Parasesarma leptosoma (Hilgendorf, 1869)		x	x
28	Parasesarma plicatum (Latreille, 1803)			x
	Xanthidae			
29	Neoliomera sp.		x	
	Squillidae			
30	Miyakella nepa (Latreille in Latreille, Le Peletier, Serville & Guérin, 1828)	x		
31	Oratosquilla oratoria (de Haan, 1844)	x		
	Balanidae			
32	Amphibalanus amphitrite Darwin, 1854	x	x	x
	Tetraclitidae			
33	Tetraclita rubescens Nilsson-Cantell, 1931		x	x
	MOLLUSCA			

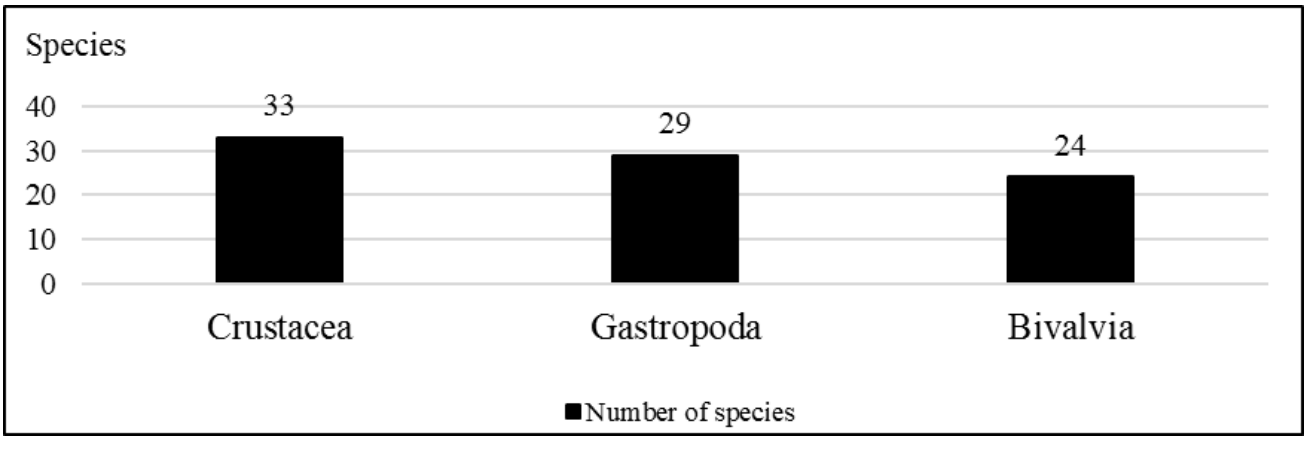
No.	Taxon	Allocation		
		Coastwise	Lan Chau Island	Hon Ngu Island
	BIVALVIA			
	Arcidae			
34	Anadara cornea (Reeve, 1844)	x		
35	Anadara inaequivalvis (Bruguiere, 1789)	x		
36	Anadara subcrenata (Lienschke, 1869)	x		
37	Barbatia domingensis (Lamarck, 1819)	x		
38	Barbatia foliata (Forsskål, 1775)	x		
39	Lunarca ovalis (Bruguière, 1789)	x		
	Cardiidae			
40	Vepricardium burnupi (G. B. Sowerby III, 1897)	x		
	Psammobiidae			
41	Asaphis violascens (Forsskål, 1775)	x		
	Mytilidae			
42	Perna vidiris Linnaeus. 1758			x
	Isognomonidae			
43	Isognomon ephippium (Linnaeus, 1758)		x	
	Ostreidae			
44	Ostraea belcheri G. B. Sowerby II, 1871	x		
45	Saccostrea glomerata (Gould, 1850)		x	x
46	Saccostrea scyphophilla (Peron & Lesueur, 1807)		x	x
	Pinnidae			
47	Atrina vexillum (Born, 1778)			x
	Anomiidae			
48	Anomia chinensis Philippi, 1849	x		
	Mactridae			
49	Mactra violacea Gmelin, 1791	x		
	Veneridae			
50	Circe scripta (Linnaeus, 1758)	x		
51	Clausinella brongniartii (Payraudeau, 1826)	x		
52	Globivenus toreuma (Gould, 1850)	x		
53	Meretrix lyrata (Sowerby, 1851)	x		
54	Meretrix lusoria (Röding, 1798)	x		
55	Paphia textile (Gmelin, 1791)	x		
56	Tivela planulata Broderip & Sowerby, 1829	x		
	Tellinidae			
57	Bosemprella incarnata (Linnaeus, 1758)	x		
	GASTROPODA			
	Ampullariidae			
58	Pomacea canaliculata (Lamarck, 1822)	x	x	x
	Planaxidae			
59	Planaxis sulcatus (Born, 1778)		x	x
	Turridae			
60	Gemmula gemmulina (Martens, 1902)		x	
	Turritellidae			
61	Turritella bacillum Kiener, 1843	x		
62	Turritella communis Risso, 1826	x		
	Neritidae			
63	Nerita albicilla Linnaeus, 1758	x	x	x
	Calyptraeidae			
64	Calyptraea chinensis (Linnaeus, 1758)	x		
	Littorinidae			
65	Echinolittorina reticulata (Anton, 1838)		x	x
66	Echinolittorina tuberculata (Menke, 1828)		x	x
67	Littoraria intermedia (Philippi, 1846)		x	x
	Naticidae			

No.	Taxon	Allocation		
		Coastwise	Lan Chau Island	Hon Ngu Island
68	Nerita balteata Reeve, 1855	x		
69	Notocochlis tigrina (Roding, 1798)	x		
70	Polinices didyma (Röding, 1798)	x	x	x
	Stenothyridae			
71	Stenothyra alba Dang et Ho, 2006	x		
	Babyloniidae			
72	Babylonia areolata (Link, 1807)	x		
	Buccinidae			
73	Alia unifasciata (Sowerby, 1832)	x		x
74	Alia sp.	x		x
75	Buccinum undatum Linnaeus, 1758	x		x
	Columbellidae			
76	Euplica scripta (Lamarck, 1822)	x		x
	Muricidae			
77	Murex trapa Röding, 1798	x		x
78	Thais clavigera (Küster, 1860)	x	x	x
79	Thais malayensis Tan & Sigurdsson, 1996	x		x
	Olividae			
80	Olivella sp.	x		x
	Cerithiidae			
81	Clypeomorus bifasciata (G. B. Sowerby II, 1855)	x		x
82	Clypeomorus pellucida (Hombron & Jacquinot, 1848)	x		x
	Cypraeidae			
83	Mauritia arabica (Linnaeus, 1758)			x
	Trochidae			
84	Monodonta canalifera Lamarck, 1816		x	x
85	Gibbula sp.	x		x
86	Umbonium vestiarium (Linnaeus, 1758)	x	x	x
Total		**63**	**23**	**33**

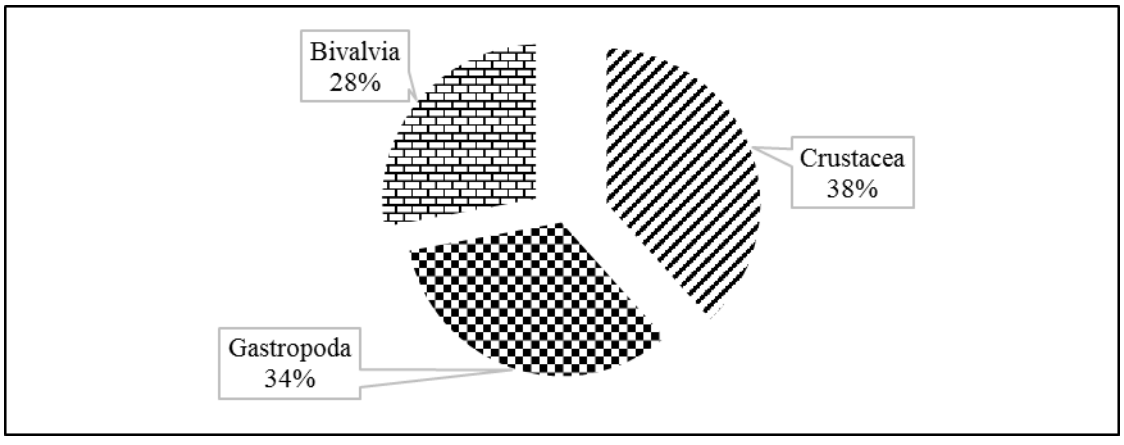
Note: x - location where species appears

Some comments from the research results:

Among the discovered species, crustaceans have the largest number of species (3 orders, 17 families, 23 genera and 33 species, accounting for 38.37%), Next are gastropod molluscs (8 orders, 17 families, 24 genera, 29 species, accounting for 33.72%), bivalve molluscs have the lowest number of species (7 orders, 11 families, 19 genera, 24 species), accounting for 27.79%), Table 1.

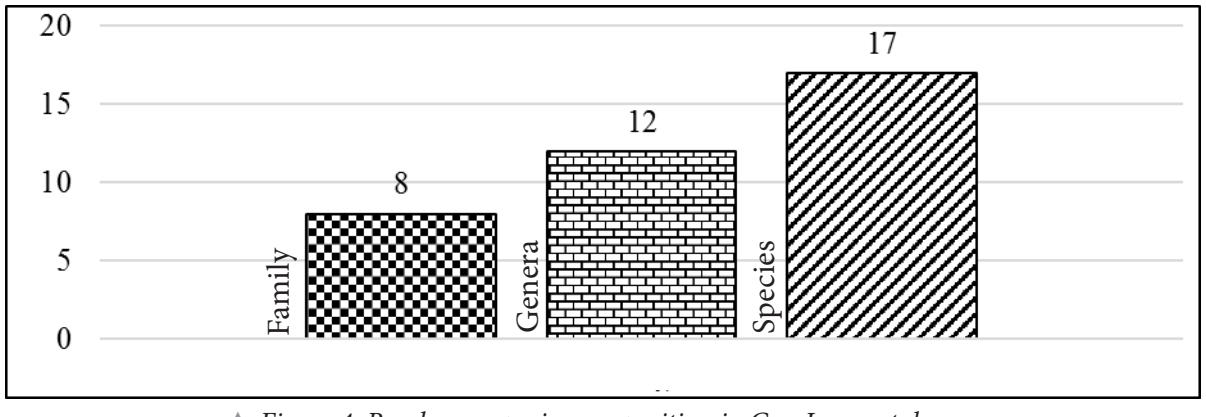


▲ *Figure 2: Number of species in the benthic group in Cua Lo waters*

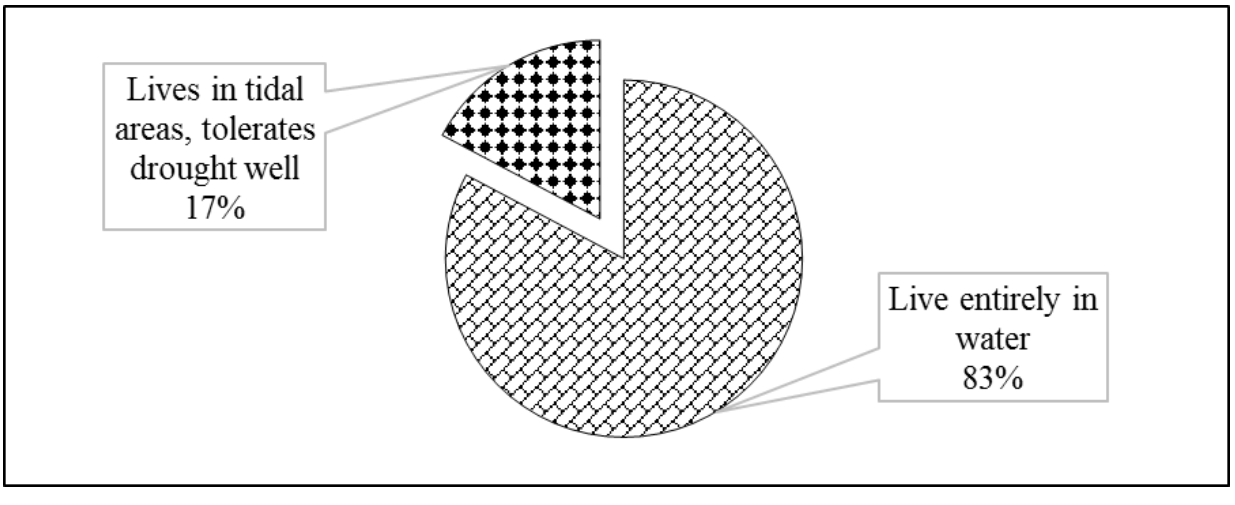


▲ *Figure 3: Percentage of species in benthic groups in Cua Lo coastal area*

Crustacea: Statistics (Table 1) show that the crustacean group has the most diverse species with 33 species. Among them, the group of crabs (Brachyura) has 17 species (8 species of swimming crabs: *Ashtoret lunaris, Charybdis anisodon, Charybdis callianassa, Charybdis feriatus, Portunus sanguinolentus, Portunus pelagicus* and *Portunus trituberculatus*). Next is the shrimp group of 9 species. Other groups only have 1-2 species.



▲ *Figure 4: Brachyura species composition in Cua Lo coastal area*



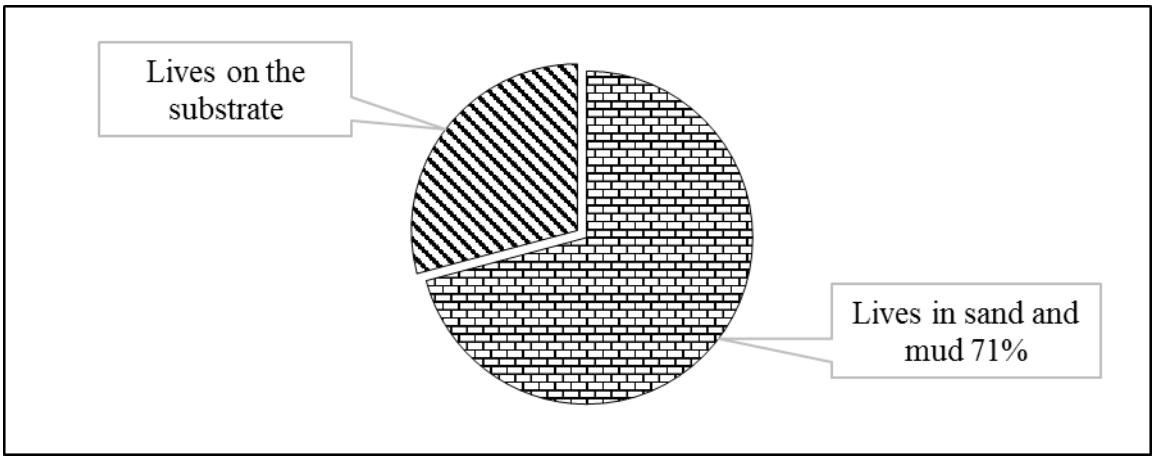
▲ *Figure 5: Gastropoda species composition living in seawater and species tolerant to land*

Gastropoda: The group of gastropod molluscs according to statistics has 29 species. Among them, there is a group that lives entirely in the seawater environment and a group that has good tolerance in dry land (living in tidal areas, clinging to the coastal bottom), Figure 5.

Gastropods live entirely in aquatic environments, with 24 species identified. For species that live in the intertidal zone and are drought tolerant, 5 species have been identified (*Planaxis sulcatus, Echinolittorina reticulata, Echinolittorina tuberculata, Littoraria intermedia and Monodonta canalifera,* Table 1 - Figure 5.

Bivalvia*:* The bivalve mollusc group has identified 24 species. Among them, the group that lives entirely on sand and mud bottoms has 17 species. There are 7 species that live on the substrate (secrete calcium or binder), filter water to get food. (*Perna vidiris, Isognomon ephippium, Ostraea belcheri, Saccostrea glomerata, Saccostrea scyphophilla , Atrina vexillum* and *Anomia chinensis*), Table 1 – Figure 5.

individuals with intact body conditions were collected for classification. Statistics show that there are 63 species of benthic animals (accounting for 73.26% of species recorded here). Living organisms distributed in this area: Crustacean group (*Diogenes mixtus Diogenes violaceus, Acetes japonicus, Paradorippe granulata, Ashtoret lunaris*…); Bivalvia (*Anadara subcrenata, Saccostrea glomerata, Ostraea belcheri*…); Gastropoda (*Babylonia areolata, Umbonium vestiarium, Littoraria intermedia*…), Table 1.



▲ *Figure 6: Composition of bivalve species living on sandy, muddy substrates and living on muddy substrates*

3.2. Distribution characteristics

Benthic animal species are distributed in the coastal area of Cua Lo according to different habitats. Benthic animals are often distributed in places with suitable habitat and conditions. Therefore, the research team divided into 3 different habitats (Lan Chau island, Hon Ngu island and the beach).

Lan Chau island: Due to human impact, mainly infrastructure is built (tourist wharf, restaurants, hotels, parking lots). Therefore, benthic animals collected in this habitat have the least diverse species composition with 23 species (accounting for 26.74% of the species recorded here), Table 1.

Hon Ngu island: This is a strictly protected place guarded by the military and accompanying tourist activities at Song Ngu pagoda. But in coastal areas there is the impact of waves along with cliffs, so benthic animals only include species suitable to live in this environment such as: *Ostraea belcheri, Echinolittorina reticulata, Echinolittorina tuberculata, Littoraria intermedia*, … Through research, statistics show that there are 33 species (accounting for 38.37% of the species recorded here) distributed on Hon Ngu island, Table 1.

Habitat in the beach area: This is a place where is often affected by humans (beaches, walking places, ships scrape the seabed, etc.). Therefore, only shell samples and some

4. CONCLUSION

Research results on benthic species composition collected in the coastal area of Cua Lo have identified 86 species belonging to 3 main groups (Bivalvia, Crustacea and Grastropoda). Crustaceans have the highest number of species with 33 species, followed by gastropods with 29 species, and bivalve molluscs have the lowest number of species with 24 species. 5 species whose genus could only be identified should be kept as sp. *(Grapsus sp.; Neoliomera sp.; Alia sp.; Olivella sp. and Gibbula sp.).*

Regarding distribution: The living environment of Lan Chau island is due to human impact, mainly built with infrastructure (tourist wharf, restaurants, hotels, parking lots). Therefore, benthic animals collected in this habitat have the least abundant species composition with the least abundant species composition with 23 species; the habitat of Hon Ngu Island has 33 species. Due to the impact of waves following cliffs, benthic animals

only include species *Ostraea belcheri, Echinolittorina reticulata, Echinolittorina tuberculata, Littoraria intermedia*…; the habitat in the beach area has 63 species of benthic animals. Crustacea (*Diogenes mixtus Diogenes violaceus, Acetes japonicus, Paradorippe granulata, Ashtoret lunaris*…). Bivalvia (*Anadara subcrenata, Saccostrea glomerata, Ostraea belcheri*…). Gastropoda (*Babylonia areolata, Umbonium vestiarium, Littoraria intermedia*…).

Currently, in the coastal area of Cua Lo (Nghe An), there is no research data on benthic groups in this area. Therefore, there has been no process of comparing the benthic species composition with previous data. Along with the short benthic research time, the number of species is still limited. Research shows that the Cua Lo benthic ecosystem is experiencing large-scale loss of benthic habitat, receives less attention than other ecosystems, and is under direct threat, due to exploitation, indirectly due to environmental pollution, swimming, garbage and other activities taking place on land. Therefore, there needs to be some solutions to preserve and protect benthic groups such as: Limit exploitation of benthic animals and coastal tidal flats along with educating the community to protect the ecosystem; Limit and prevent the exploitation of species at risk of biodiversity loss; build a strict conservation area for benthic animals at home and offshore; build and develop valuable domestic and international benthic groups ▪

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1. INTRODUCTION

Currently, the circular economy as well as the green economy and green growth are economic models that aim to effectively use and save resources and recycle waste, contributing to economic efficiency and environmental sustainability. Circular economy is considered an inevitable trend of the times and the green industrial revolution of the 21st century. Accordingly, developing green and sustainable agriculture and processing industry is being focused on by the Government (Decision No. 687/QD-TTg dated June 7th, 2022 of the Prime Minister approving the Circular Economy Development Project in Vietnam and Decision No. 882/QD-TTg dated July 22nd, 2022 of the Prime Minister approving the National Action Plan on green growth for the period of 2021-2030). The application of useful microbial strains (bacteria, fungi, actinomycetes, yeast...) as well as their secondary products in the circular, green and sustainable production chain of livestock, crop cultivation and food processing industry, is an application direction that is being widely developed (increasing health, productivity, quality of crops, livestock, post-harvest products; treating waste water, agricultural and industrial by-products into useful products such as fertilizer, animal feed, natural materials, irrigation water...). In particular, microbial strains have the ability to biosynthesize extracellular enzymes (cellulose, proteinase, lipase, amylase...) and resist pathogenic bacteria (such as *Escherichia coli, Staphylococcus aureus, Bacillus cereus, Pseudomonas aerigunosa*, *Bacillus subtillis*, *B. megaterium, Lactobacillus casei, L. plantarums, Rhodopseudomonas, Azotobacter, Azospirillum, Enterobacter…), Actinomycetes Streptomyces, Actinomyces...*; microfungi such as *Trichoderma harzianum, Aspergilus tubingensis*... have been commonly used to replace and reduce the amount of food, fertilizer, antibiotics and other chemicals (Sindhu et al., 2018; Inamuddin et al., 2022).

However, to increase the effectiveness of practical applications, research and selection of multi-active strains is necessary. Plant endophytic fungi (especially in herbal plants) represent one of the potential alternatives as they have

Biological activity research of endophytic fungi on Huperzia javanica plant with application orientation in the circular economy

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Abstract

The application of beneficial microorganisms as well as their secondary products in the livestock, agriculture, and food industry supply chains for sustainable green production is a developing trend. The research direction of selecting multi-activity strains to enhance the effectiveness of practical applications has been receiving attention. This study aims to select endophytic fungal strains on Huperzia javanica plant in Vietnam that have the ability to produce multi-extracellular enzymes and multi-resistance to pathogenic microorganisms by determining enzyme activity and testing antimicrobial activity. The results showed the following: (1) All 9 strains have the ability to produce 1 to 5 types of enzymes and inhibit 1 to 5 pathogenic microorganisms with potential activities; Strains TLC11 and TLC9 produce 4÷5 enzymes (cellulase, lipase, protease, phosphatase and β-galactosidase) with the highest hydrolysis zone diameters of 22÷25 mm (protease) and 20÷23 mm (lipase); (2) Strain TLC13 inhibits all 5 tested microbial strains Escherichia coli, Staphylococcus aureus, Candida albican, Bacillus cereus, Pseudomonas aerigunosa) with the highest activity against 3 species B. cereus (24±1.2 mm), P. aerigunosa (26±1.1 mm) and C. albican (36±1.5 mm); Strains TLC10 and TLC19 are resistant against 4/5 tested microorganisms except S. aureus (TLC10) and E. coli (TLC19). These strains could be the potential sources for further in-depth research aiming to expand their applications in sustainable agriculture, aquaculture, and industry production fields.

***Keywords*:** *Biological activity, Huperzia javanica, endophytic fungi, extracellular enzyme, antimicrobial.*

JEL Classification: *N50, N53, N57, O13.*

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demonstrated high efficiency in the production of active metabolites with new biological properties, not only antibacterial properties but also other wide-range biological activities. These species inhabit various tissues and organs of healthy plants at certain or all stages of their life cycle, in addition to being able to biosynthesize biologically active compounds corresponding to the host plant, they can also produce other active substances (enzymes, antibacterial substances, protein, alkaloids, polyketides ...) that help the host plant increase growth, inhibit disease, and withstand saltwater - drought - temperature as well as can be applied in the food, agriculture - fishery, environmental and pharmaceutical industries (Daniel et al., 2022; Fatima et al., 2022; Cripwell et al., 2021; Lu et al., 2022; et al., 2021; Jouda et al., 2014).

H. javanica is a precious medicinal plant (currently under conservation) belonging to the Lycopodiaceae family, known for supporting the treatment of some neurological diseases, rheumatism, and hepatitis, diarrhea... *H. javanica* likes moisture and shade, grows on moist soil with a thick layer and lots of humus, at an altitude of 1,000-1,500m; distributed in China, India, Japan and Vietnam (Sun et al., 2015). There have been many published studies on the biological activities of plant endophytic fungi strains in other medicinal plants, however, studies on *H. javanica* are almost non-existent. This study focuses on surveying and selecting plant endophytic fungi strains in Vietnam. *H. javanica* has the ability to produce

multi-enzymes and multi-resistance to pathogenic microorganisms with the goal of further research and application in circular and sustainable food, agricultural - industrial - fishery - pharmaceutical production which will contribute to reducing environmental pollution.

2. MATERIALS AND METHODS

2.1. Research materials

In previous research, 9 plant endophytic fungi strains were isolated and selected from the *H. javanica* tree distributed in Ha Giang (Vietnam) with the ability to biosynthesize the active pharmaceutical ingredient huperzine (an alkaloid that supports treatment of dementia, especially Alzheimer's disease). In this study, the strains were further researched on other biological characteristics in order to survey and select strains that are multi-enzyme-synthesizing and multi-resistant to pathogenic microorganisms towards other applications in circular and sustainable production of agriculture, industry, fishery and pharmaceuticals. Strains include: Neurospora calospora TLC9, N. calospora TLC10, N. calospora TLC11, Schizophyllum commune TLC12, Epicoccum sorghinum TLC13, Alternaria tenuissima TLC14, Daldinia sp. TLC19, Cephalotrichum sp. TLC20, Schizophyllum sp. TLC22. Tested microbial strains: *E. coli* (ATCC 25922), *S. aureus* (ATCC 33591), *C. albican* (ATCC 10231), *B. cereus* (ATCC 11778), *P. aerigunosa* (ATCC 27853) were provided by the Center for Breeding and Preserving microbial genetic resources, provided by the Institute of Biotechnology.

2.2. Research Methods

2.2.1. Method for determining the ability of fungal strains to produce extracellular enzymes

Determination of amylase production ability

Fungal strains were grown on PDB liquid medium at 28°C for 5-7 days. Prepare a substrate medium plate containing 20 g/l agar supplemented with 1% starch, drill wells with a diameter of 8 mm, each well add 100 µl of fungal extracellular fluid. The negative control is PDB medium without fungal strains. Keep the plate at 4°C overnight to allow the enzyme to diffuse into the medium. Continue incubation at 37°C for about 24 hours for the enzyme to activate. The relative activity of the enzyme was determined based on the difference D-d (mm). Where D is the resolution ring diameter (mm), d is the agar hole diameter (mm). D-d > 25 mm: a very strong enzyme activity; D-d = 20-25 mm: a strong enzyme activity; D-d = 10-20 mm: an average enzyme activity; D-d < 10 mm: a weak enzyme activity. The experiment was repeated 3 times.

Determine the ability to produce protease, cellulase, lipase and phosphatase

Carry out the same method to determine the amylase production ability of fungal strains with substrate medium supplemented with 1% casein, carboxyl methyl cellulose (CMC), Tributylin and $Ca_3(PO4)_2$ to determine the ability to produce corresponding enzymes including protease, cellulase, lipase and phosphatase.

Determination of β-galactosidase enzyme activity

X-gal was dissolved in dimethyl sulphoxide reached a concentration of 20µg/mL, stored in the dark at -20^{0}C. After sterile autoclaving, the PDA medium was poured into a plate, then 50 µl of X-gal indicator was spread evenly on the surface of the PDA agar plate medium. Inoculate and score plant endophytic fungi strains on agar plate medium with X-gal indicator. Cultured in a 28°C incubator for 3-10 days, endophytic fungal strains that produce a blue color on the indicator plate are strains capable of synthesizing the enzyme β-galactosidase. The experiment was repeated 3 times.

2.2.2. Agar plate diffusion method

The anti-microbial activity was determined by the diffusion method on agar plates. The researched fungal strains were cultured in PDB medium for 5-7 days and the mushroom extract was collected. Drop 100µl of fungal extract into each well created on an LBA medium plate that has been inoculated with control microorganisms. A well of PDB environment was used as a negative control, and a well of the antibiotic ampicillin at a concentration of 1 mg/ml was the positive control. The plate is kept at 4^{0}C for 2 - 4 hours to allow the enzyme to diffuse into the medium, then the plate is incubated at 37^{0}C for 24 hours. Antibacterial activity is determined by the diameter of the sterile ring D-d (mm), in which: D is the diameter of the sterile ring, d is the diameter of the well. The experiment was repeated 3 times.

3. RESULTS AND DISCUSSIONS

3.1. Enzyme-producing ability of plant endophytic fungi strains

9 plant endophytic fungi strains were tested for their ability to produce 6 extracellular enzymes, including cellulose, lipase, protease, amylase, phosphatase and β - galactosidase.

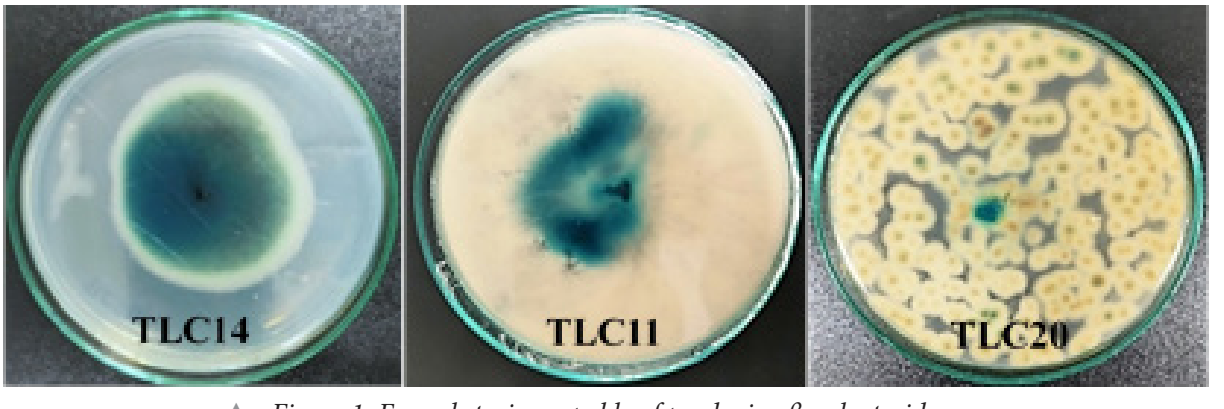
The ability to produce extracellular enzymes of the 9 studied fungal strains is shown in Table 1, Figure 1 and Figure 2, showing that all 9 strains are capable of producing from 1 to 5 types of tested enzymes; among

them, the number of strains capable of producing lipase and protease accounts for the highest proportion with 7 strains (77.77%), followed by the number of strains producing cellulose (6 strains; 66.66%), the number of strains producing phosphatase accounts for the highest proportion with rate of 33.33% (3 strains), 2 strains produced β -galactosidase (rate 22.22%) and only 1 strain TLC10 produced amylase (11.11%) with low activity. Among the enzymes produced by the studied strains, protease have the strongest activity expressed in fungal strains, 3 strains (TLC9, TLC11 and TLC12) have hydrolysis circle diameters from 20 ÷ 25 mm, 4 strains (TLC13, TLC14, TLC20 and TLC22) hydrolysis ring diameter over 25 mm. Of the 7 lipase-producing strains, 6 strains (TLC9, TLC10, TLC11, TLC14, TLC19 and TLC22) have strong lipase activity (dialysis circle diameter from 20 ÷ 25 mm).

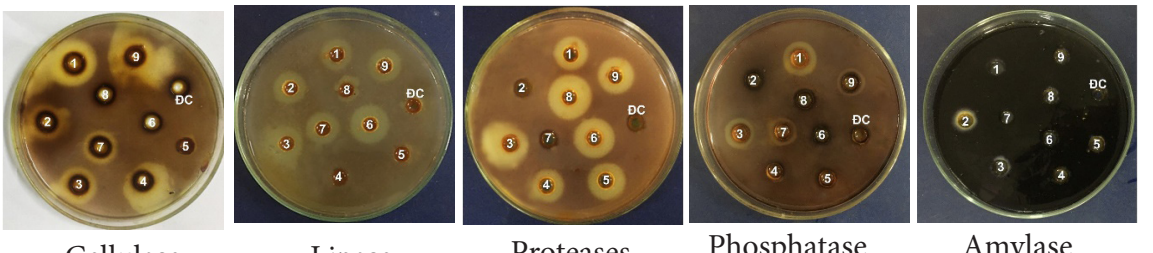
When cultivating the fungus on a medium containing X-gal indicator, the strains stain blue, showing the ability to produce β-galactosidase. Strains with faster staining times and darker colors will have a higher ability to produce β-galactosidase. Among the 3 strains with β-galactosidase-producing activity, strain TLC14 has colonies that turn green in a very short time of colony formation (after 2 days of culture), and its strong staining ability proves its ability to produce β-galactosidase highly. Meanwhile, the remaining 2 strains (TLC11 and TLC20) have colonies that turn green more slowly (after 3 days of culture) and the color staining of the colonies is not uniform, so they may not have a high ability to produce β-galactosidase.

Table 1. Enzyme-producing ability of the studied fungal strains

No.	Strains	Enzyme activity (mm)					
		Cellulase	Lipase	Proteases	Phosphatase	Amylase	β - galactosidase
1	TLC9	12±0.9	20±1.4	25±1.5	8±0.7	-	-
2	TLC10	4±0.6	23±1.2	-	-	5±0.6	-
3	TLC11	9±0.8	23±1.1	22±1.2	6±0.5	-	+
4	TLC12	7±0.5	-	22.5±1.2	-	-	-
5	TLC13	-	-	31±1.6	-	-	-
6	TLC14	-	28±1.7	32±1.5	-	-	+
7	TLC19	3±0.3	25±1.5	-	3±0.3	-	-
8	TLC20	-	10±0.9	34±1.7	-	-	+
9	TLC22	11±0.9	24.5±1.2	28±1.3	-	-	-
10	Control (-)	-	-	-	-	-	



▲ *Figure 1. Fungal strains capable of producing β-galactosidase*



▲ *Figure 2. Enzyme biosynthesis ability of fungal strains (1. TLC9, 2. TLC10, 3. TLC11, 4. TLC12, 5. TLC13, 6. TLC14, 7. TLC19, 8. TLC20, 9. TLC22, Control (-): negative control)*

Among the 6 enzymes tested, strain TLC11 showed the ability to produce 5/6 types except amylase enzyme; then is strain TLC9, which produces 4/5 types of enzymes; 4 strains produce 3 types of enzymes including: TLC10, TLC19, TLC20 and TLC22 and the only strain TLC13 only strongly produces 1 type of protease enzyme with an active circle of 31±1.6 mm. Notably, the three strains TLC9, TLC10 and TLC11 are the same *N. calospora* species but have different enzyme-producing abilities.

According to previous studies, enzymes are biological catalysts of more than 5,000 types of biochemical reactions that help promote rapid metabolism in cells. Microbial metabolism produces different types of enzymes and is a large source of natural enzymes. Proteases are one of the three largest groups of industrial enzymes, accounting for about 60% of total global enzyme sales; hundreds of proteases have been commercialized and used in detergents, food processing, animal feed additives, leather processing, waste treatment, pharmacology and drug production (Sindhu et al., 2018). Cellulases are important enzymes both industrially and naturally, playing a key role in the global carbon cycle. Cellulase hydrolysis can serve a "dual" purpose: reducing plant waste, converting biofuels to fuel, and narrowing the growing dependence on fossil fuels and for other industrial purpose such as in pulp, food, wine productions... Some cellulose-producing bacteria such as Pestalotiopsis sp., Microsphaeropsis sp., Sclerocystis sp., Cephalosporium sp., Penicillium sp., Fusarium oxysporum, Aspergillus sp., Penicillium chrysogenum, Xylaria sp... have been isolated from *Acanthus ilicifolius*, *Zea mays, Sabina chinensis, Taxus chinensis, Keteleeria evelyniana, Pinus massoniana...* (Fatima et al., 2022; Sindhu et al., 2018). Amylase is an enzyme that hydrolyzes the alpha bond of polysaccharides to create glucose and maltose, that is used in food, beverages, and medicine and produced naturally by many different species of fungi; including the plant endophytic fungi species such as plants of *P. microspore, A. oryzae and P. chrysogenum*, *Rhizophora mucronata, Avicennia ofcinalis, A. marina and Asclepias sinaica* (Fatima et al., 2022; Cripwell et al., 2021). Lipase is an enzyme that decomposes triglycerides into free fatty acids and glycerol, with great applications in the food industry: increasing vegetable oil processing productivity and increasing aroma in the baking and dairy industries. The best source of lipase is exploited from many fungal species such as Rhizopus, Mucor, Geotrichum, Pencillium, Aspergillus, Humicola; In addition, there are plant endophytic fungi species such as *R. oryzae, Cercospora kikuchii, Lasiodiplodia theobromae* from Tithonia diversifolia and Cocos nucifera trees (Fatima et al., 2022; Sindhu et al., 2018). The ability to utilize insoluble phosphate in soil can be improved by using phosphatase enzymes to help plants grow and develop better; Fitriyana and Ainy (2019) isolated plant endophytic fungi strain from *R. mucronate* roots with phosphatase activity. β-Galactosidase is an exoglycosidase that hydrolyzes the β-glycosidic bond which formed between galactose and its organic part; β-galactosidase is used in dairy products such as yogurt, sour cream, and some cheeses that are enzymatically treated to break down any lactose before human can consume (Eriana et al., 2000).

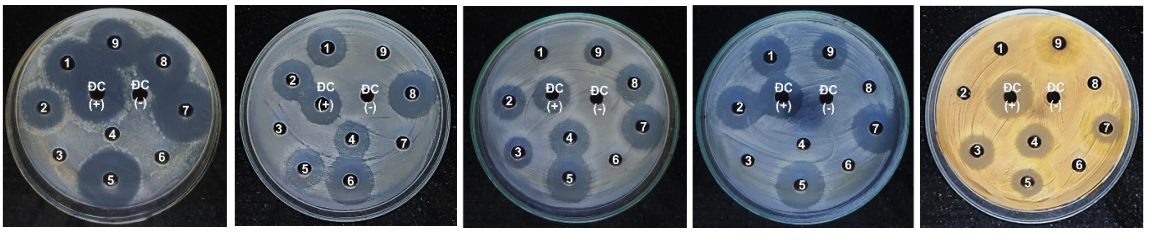
Research results on *H. javanica* plant species show that the species has ability to produce the above enzymes is almost unpublished. These positive results show that this species is a source of raw materials for further research to obtain high yields of natural enzymes aimed at applications in sustainable agro-industrial-fishery production such as applications in creating animal feed, processing agricultural, industrial and fishery waste into organic fertilizer for farming and replacing chemical fertilizers for soil improvement...

3.2. Resistance to pathogenic microorganisms of the studied fungal strains

Evaluate the resistance to pathogenic microorganisms of 9 strains of studied fungi with 5 strains of tested microorganisms, including: 2 strains of gram-positive bacteria (B. cereus, S. aureus), 2 strains of gram-negative bacteria (*E. coli, P. aeriginosa*) and 1 yeast strain *C. albicans*. The results shown in Table 2 and Figure 3 show that 7 fungal strains (77.77%) are resistant to *B. cereus* bacteria; 6 strains (66.66%) were resistant to *E. coli* bacteria as well as to *C. albican* yeast; 5 strains (55.55%) were resistant to *P. aerigunosa*; 4 strains were resistant to *S. aureus*. All strains have potential activity against tested pathogenic microorganisms with inhibition zone diameters ranging from 9±0.4 to 37±1.4 mm. In particular, strain TLC13 has the ability to inhibit all 5 strains of tested microorganisms with almost the highest activity with 3 species of tested microorganisms ranging from 24±1.2 mm (*B. cereus*), 26±1.1 mm (*P. aerigunosa*) and 36±1.5 mm (*C. albican*); The two strains TLC10 and TLC19 are both resistant to 4/5 tested microorganisms. Strain TLC19 is strongly resistant to *B. cereus, P. aerigunosa* and *C. albican*; the 4 strains were resistant to 3/5 of the tested microorganisms and the strain was resistant to only 1 type of E. coli bacteria, strain TLC14.

Table 2. Resistance to pathogenic microorganisms of the studied fungal strains

No.	Fungal strains	Inhibition zone for the growth of tested pathogenic microorganisms (mm)				
		G (+) bacteria		Bacteria G (-)		Yeast
		B. cereus	*S. aureus*	*E. coli*	*P. aerigunosa*	*C. albicans*
1	TLC9	-	-	16±0.9	20±1.1	28±1.4
2	TLC10	15±0.5	-	17±0.4	23±0.9	17.5±0.3
3	TLC11	13±0.4	15±0.6	-	-	-
4	TLC12	17±0.5	16±0.7	14±0.4	-	-
5	TLC13	24±1.2	13±0.6	16±0.5	26±1.1	36±1.5
6	TLC14	-	-	26±0.9	-	-
7	TLC19	22±0.9	12±0.3	-	25.5±1.2	37±1.4
8	TLC20	18±0.8	-	25±1.2	-	33±1.3
9	TLC22	9±0.4	-	-	18±0.9	28±1.2
10	Control (+)	18±0.8	24±1.1	16±0.5	23±1.2	36±1.3
11	Control (-)	-	-	-	-	-



▲ *Figure 3. Resistance to pathogenic microorganisms tested against C. albican, E. coli, B. cereus, P. aerigunosa, S. aureus of fungal strains (1. TLC9, 2. TLC10, 3. TLC11, 4. TLC12 , 5. TLC13, 6. TLC14, 7. TLC19, 8. TLC20, 9. TLC22, Control (-): negative control, Control (+): positive control)*

For a long time, antibiotics derived from filamentous fungi have been known and used effectively in treating diseases of humans, animals, and plants. The search for new antibiotics of natural origin from microorganisms is of interest. According to Balick and Cox, in 1996, out of 119 chemical compounds, at least 90 were of plant origin. These are drugs that are being used in more and more countries. The fungal strain Nigrospora sphaerica URM-6060 isolated from the leaves of the medicinal plant Indigofera suffruticosa produces biologically active substances with pharmaceutical potential such as hydrolyzed tannins, alkaloids, cinnamic derivatives with antibacterial activity against both positive Gram (+) and negative Gram (-) bacteria (Santos et al., 2015). Jouda et al (2014) isolated three polypeptides, penealidins AC (134-136), with activity against *Acinetobacter sp.* and *E. coli* from the endophytic fungus Penicillium sp. CAMMC64 isolated from the leaves of Garcinia nobilis (Clusiaceae) distributed in Cameroon. Extracts of plant endophytic fungi strains *E. nigrum, F. Tricinctum* and Phoma sp. isolated from *Dendrobium devonianum* and *D. thyrsiflorum* plants that are resistant to bacteria *B. subtilis, C. albicans, E. coli* and *S. aureus*; strains Alternaria sp., Bjerkandera sp., Diaporthe sp., Penicillium sp. and Xylaria sp. isolated from *Schinus terebinthifolius* have the ability to resist *C. albicans, P. aeruginosa* and *S. Aureus* (Daniel et al., 2022).

Studies on plant endophytic fungi species resistant to pathogenic microorganisms in *H. javanica* plants have not been published. Plant endophytic fungis trains with a broad resistance spectrum and potential antibacterial activity such as TLC13,

TLC19 and TLC10 may be a potential source of raw materials for the search and discovery of new anti-bacterial active ingredients that can be applied in human life such as in the field of animal husbandry, preservation and post-harvest processing...

4. CONCLUSION

Research and application of plant endophytic fungi strains (especially plant endophytic fungi in herbal plants) in circular economy is a potential research direction. Studies on the plant's ability to produce enzymes and resist pathogenic microorganisms have not been published yet. This study has screened and selected a number of plant endophytic fungi strains of the *H. javanica* plant that have the ability to biosynthesize multiple extracellular enzymes and are multi-resistant to pathogenic microorganisms. Among the 6 enzymes tested, strain TLC11 showed the ability to produce 5/6 types except amylase enzyme; then is strain TLC9, which produces 4/5 types of enzymes; 4 strains produce 3 types of enzymes include: TLC10, TLC19, TLC20 and TLC22. Protease and lipase are the two activities that are most strongly expressed in active strains, with hydrolysis ring diameters from 22 ÷ 34 mm (protease) and 20 ÷ 28 mm (lipase). Among the 5 types of pathogenic microorganisms tested, strain TLC13 inhibited all 5 tested strains of microorganisms with almost the highest activity against 3 species B. cereus (24±1.2 mm), P. aerigunosa (26±1.1 mm) and C. albican (36±1.5 mm); 2 strains TLC10 and TLC19 were resistant to 4/5 tested microorganisms except S. aureus (TLC10) and E. coli (TLC19) ; 4 strains were resistant to 3/5 tested microorganisms. The research strains are capable of producing extracellular enzymes with strong activity, have a relatively broad spectrum of resistance to pathogenic microorganisms with potential inhibitory activity: TLC9, TLC11, TLC13, TLC10, TLC19. These strains will be a potential source of raw materials for application in the fields of sustainable agriculture - industry - fisheries – pharmaceuticals productions. However, further research is needed such as identifying anti-bacterial active ingredients, the activity of antibacterial substances and extracellular enzymes, fermentation conditions to increase productivity and the absorption of antibacterial enzymes, substances as well as as well as testing their application in practice, thereby providing specific application solutions for each industry such as livestock farming, cultivation, post-harvest processing and preservation, food industry and environmental treatment.

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Apply hydrodynamic modeling method and artificial intelligence model to evaluate water quality of Dao river, Nam Dinh

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Abstract

The section of Dao river that flows through Nam Dinh city plays a very important role in the socio–economic development of Nam Dinh province. The water of this section also serves as raw water input for Nam Dinh Water Plant which supplies clean water for domestic and industrial use in Nam Dinh city. Therefore, the management and protection of the water quality is of great significance. The study develops artificial intelligence (AI) model to simulate the water quality of Dao river, based on the results of hydrodynamic simulation and water quality in the hydraulic model MIKE11. This study applies hydrodynamic modeling method (MIKE11) and artificial intelligence (AI) model to evaluate water quality of Dao river. The results of this study show that the method of using the MIKE 11 model combined with the AI model to simulate river water quality is relatively accurate. The results show that the wastewater treatment plant on the Dao river is generally still in good condition and has the ability to receive additional waste sources if the waste sources are treated before being discharged into the environment.

Key words: *water resource management; urban water supply; Dao river, MIKE model, water quality, Artificial Intelligence model; MLP-ANN.*

JEL Classifications: *O13, Q53, R11.*

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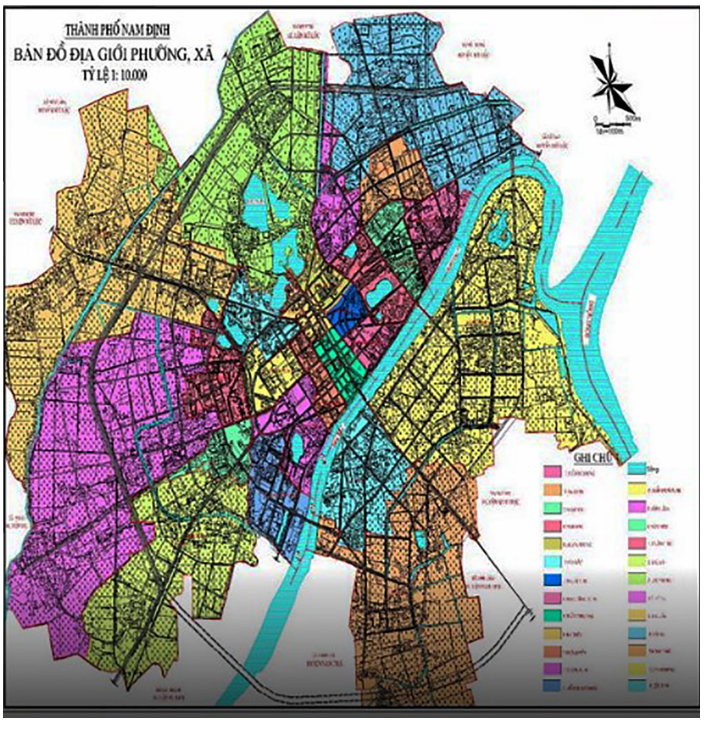
1. INTRODUCTION

Dao river is a distributary of the Red River and a tributary of the Day river, flowing in Nam Dinh province, starting from the Red River and sending part of the water flowing in the South direction (the boundary between Nam Dinh city, the districts: My Loc, Vu Ban, Y Yen, Nam Truc, Nghia Hung), then flows into the Day river and flows into the East Sea. The total length of the river is 33.5 km (Figure 1). (Xuân, T.T, 2012). As a source of clean water for the majority of residents in Nam Dinh city, Dao river is also an area that receives domestic and industrial wastewater from the city's river/drainage canal system through three main outlets: the pumping station Quan Chuot, Kenh Gia pumping station and Coc Thanh pumping station. Currently, due to water flowing from the Red River and pressure from wastewater sources that have not been thoroughly treated, the Dao river water source is at risk of being polluted, affecting the water supply safety of Nam Dinh city, therefore protecting water quality and providing control solutions to protect Dao river's water quality is a very urgent issue.

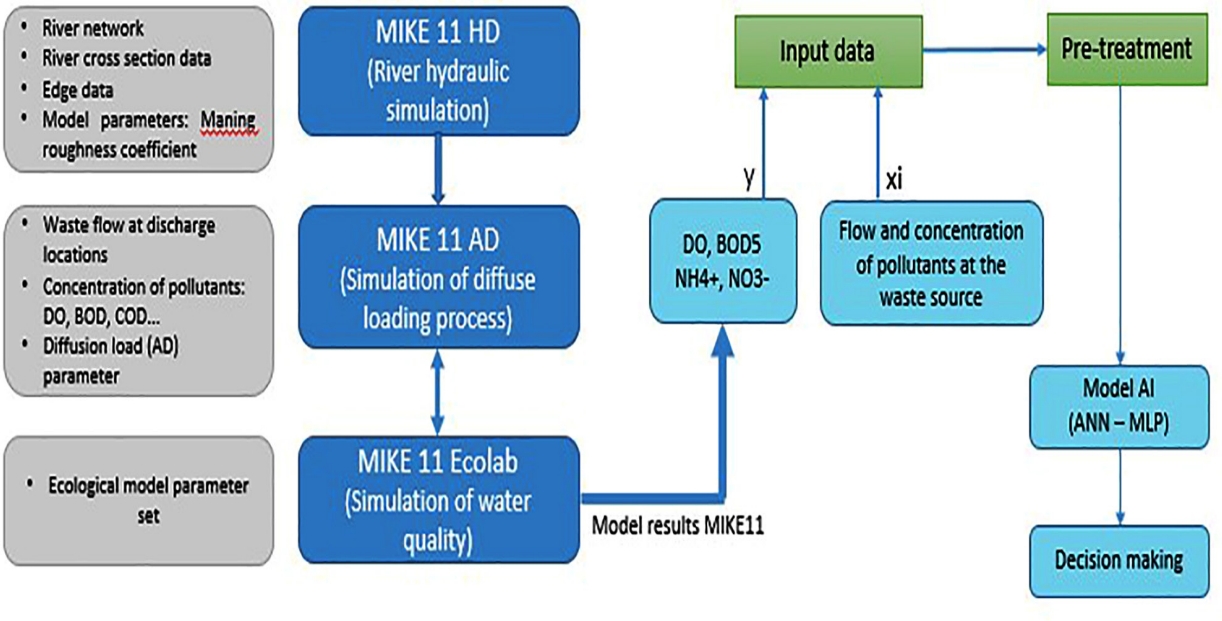


▲ *Figure 1. Map of Dao river flowing through Nam Dinh city*

Calculating and simulating spatial and temporal variations of pollutants plays an important role in assessing and controlling water quality. With the development of information technology as well as water quality modeling, more and more water quality simulation models are born and developed. Some popular mathematical models that have been developed include QUAL, WASP, QUASAR, MIKE Ecolab. These models belong to the group of numerical models, which model the water spreading process on river and canal systems. The advantage of this group of models is that it can provide information to assess water quality over space and time. However, setting up the model is relatively complicated and takes a lot of time, requiring model users to have specialized knowledge in calibrating, testing and evaluating model results. Especially, in developing countries like Vietnam, due to the complexity in setting up the model, it will be very difficult to transfer the model to local management agencies for use. Therefore, developing simple, accessible and easy-to-use models is an urgent requirement.

Recently, AI models for water quality prediction simulation have been widely applied due to their fast calculation ability with high reliability and efficiency. Besides, hydrological processes are generally non-linear processes in nature, changing over space and time such as flow and water quality. Therefore, the description of the above processes and factors needs to be analyzed non-linearly. When the data is large enough, along with the algorithm and coefficients of the AI model set appropriately, the model is capable of simulating factors with high performance and accuracy, and can replace Numerical hydraulic model.

Reality shows that AI models have outstanding advantages and are suitable in managing, evaluating, simulating, and predicting effective water quality in a number of countries around the world. However, the approach of using AI technology to simulate water quality is still one of the relatively new research directions in the world today. In Vietnam, so far there have not been many studies evaluating water quality simulation using AI networks. One of the reasons why AI models have not been widely used is due to the lack of data to process and then make predictions with the most optimal accuracy for AI models. Compared to numerical models, AI technology does not require users to have in-depth professional knowledge because the analysis and data processing tasks are hidden behind the scenes. The technology also provides quick calculation results, suitable for simulation, water quality prediction as well as decision support in pollution control. Therefore, the research will combine both the MIKE11 model and the AI model to increase the reliability of the AI model, in which the MIKE11 model is used to create a database under different scenarios along with data. Measurement data is available as input to the AI model. This article presents some results from the method of using the MIKE 11 model combined with an AI model to simulate water quality for Dao river in Nam Dinh province.



▲ *Figure 2. Research method diagram*

2. METHODOLOGY

The study uses a combination of MIKE11 models (DHI. MIKE11, 2017) and AI models (Ighalo, J.O et al 2021) in computational simulation of Dao river water quality. In particular, the mathematical modeling method uses one-dimensional MIKE HD, AD and Ecolab models to simulate water quality developments and create an input database for the AI model. Research using the MIKE model to simulate hydraulics and water quality in the river basin with data series from 2016-2020 in daily steps to calibrate and verify the model, then simulate quality results. Water is used as input data for the AI model. The AI model uses AI algorithms to build regression relationships between water quality at a number of control locations and variables that affect quality at these control locations (river water flow, concentration of pollutants, pollutants and flow at waste sources). *Figure 2* presents the connection diagram between the hydraulic model, water quality model and AI model used in this study.

2.1. Model MIKE11

MIKE11 is a one-dimensional hydrodynamic model for simulating irregular flows in rivers and open channels. MIKE11 was developed by the Danish Hydraulics Institute, in which the hydrodynamics (HD) module using flow calculation is the main module.

The basic characteristic of the MIKE11 Model system is a comprehensive module structure with many types of modules added to each simulation of phenomena related to the river system. In addition to the hydrodynamics (HD) module, MIKE includes other modules such as:

- Hydrology module (NAM) uses data interpolation;
- The substance spread module (AD) uses the properties of substance spread (saltiness, suspension or decomposition in open channels...) to simulate the diffusion loading process of those compounds;
- Ecological module (Ecolab) simulates biological transformation processes of compounds in rivers. This module must be accompanied by the loading - diffusion (AD) module. Diffusion (AD) is used to simulate the diffusive transport of such compounds.

Hydrodynamic module (HD)

To calculate the flow in the river channel, the MIKE11 model uses the one-dimensional Saint Venant equation system (momentum and substance conservation equations) and applies the 6-point alternating difference scheme Q,H of Abbott, and Ionescu. (Chau, K.W,2006):

Continuous equation:

$$\frac{\partial Q}{\partial x}+\frac{\partial A}{\partial t}=q \qquad (1)$$

The momentum equation:

$$\frac{\partial Q}{\partial t}=\frac{\partial\left(\alpha\frac{Q^2}{A}\right)}{\partial x}+gA\frac{\partial h}{\partial x}+\frac{gQ|Q|}{C^2\mathrm{AR}}=0 \qquad (2)$$

In which: Q- Flow rate (m3/s); A- Cross-sectional area (m2); q- Influent flow per unit length along the river (m2/s); C- Chezy coefficient; α- Momentum correction coefficient; R- Hydraulic radius (m).

Agent spreading module (AD)

The AD module is based on the solute conservation equation [5,6]:

$$+\frac{\partial QC}{\partial x}-\frac{\partial}{\partial x}\left(AD\frac{\partial C}{\partial x}\right)=-AKC+C_2q \qquad (3)$$

In which: A: Cross-sectional area (m2); C: Concentration (kg/m3); D: Dispersion coefficient; q: Influent flow per unit length along the river (m3/s); K: Biodegradation coefficient (K is only constructed when the phenomena or processes considered are related to biochemical reactions).

Ecolab ecological module

The dynamics of the advection of state variables in ECO Lab can be described by the transport equations of non-conservative matter, of the form (4):

$$\frac{\partial c}{\partial t}+u\frac{\partial c}{\partial x}+v\frac{\partial c}{\partial y}=D_x\frac{\partial^2 c}{\partial z^2}+D_y\frac{\partial^2 c}{\partial z^2}+S_c+P_c \qquad (4)$$

In there:

c: Concentration of ECO Lab state variable;

u, v: Flow velocity components;

D_x, D_y: Diffusion coefficients in x and y directions;

S_c: The source of birth and the source of loss;

P_c: Processes in ECOLab;

The transport equation can be rewritten as follows:

$$\frac{\partial c}{\partial t}=AD_c+P_c \qquad (5)$$

In particular, the AD_c group represents the rate of change in concentration caused by advection and diffusion processes (including sources of generation and loss).

When calculating the concentration variations for the next step, a numerical ECOLab equation is substituted for the time-integral transport equations. Another approximation method used in ECOLab is to consider the advection–advection component AD_c as constant over a time step. Solving both components of ECOLab's ordinary difference equation is a combination of the rate of change caused by internal processes and advection-diffusion processes (6).

$$c(t+\Delta t)=\int_t^{t+\Delta t}\left(P_c(t)+AD_c\right)dt \qquad (6)$$

The advective-diffusive component is approximated by the following formula:

$$AD_c = \frac{c^* + c^n(t+\Delta t) - c^n(t)}{\Delta t} \quad (7)$$

In which: the instantaneous concentration c* is given by the state variable transmission process in ECOLab when matter is conserved throughout the cycle of using the AD module.

The river network diagram simulating water quality developments on the Dao river system is presented in Figure 3. Inputs for the HD hydraulic modules, AD diffuse load and Ecolab of the MIKE 11 numerical model include: network river, river profile data, boundary data, roughness coefficient parameters (MIKE11 HD); flow rate, concentration of pollutants and source location, parameter sets of diffuse (MIKE11 AD) and ecological (MIKE11 Ecolab) loading modules. Simulated water quality factors include BOD5, NH4 -N, NO3-N, DO and temperature.

Upper boundary (flow boundary or water level) is the actual flow or water level measured at the upper nodes of the calculation diagram.

The lower boundary (water level boundary) is the actual measured or calculated water level at the lower nodes of the calculation diagram, usually tide level stations. Boundary types and calculation and simulation diagrams are shown in Table 1, Figure 2.

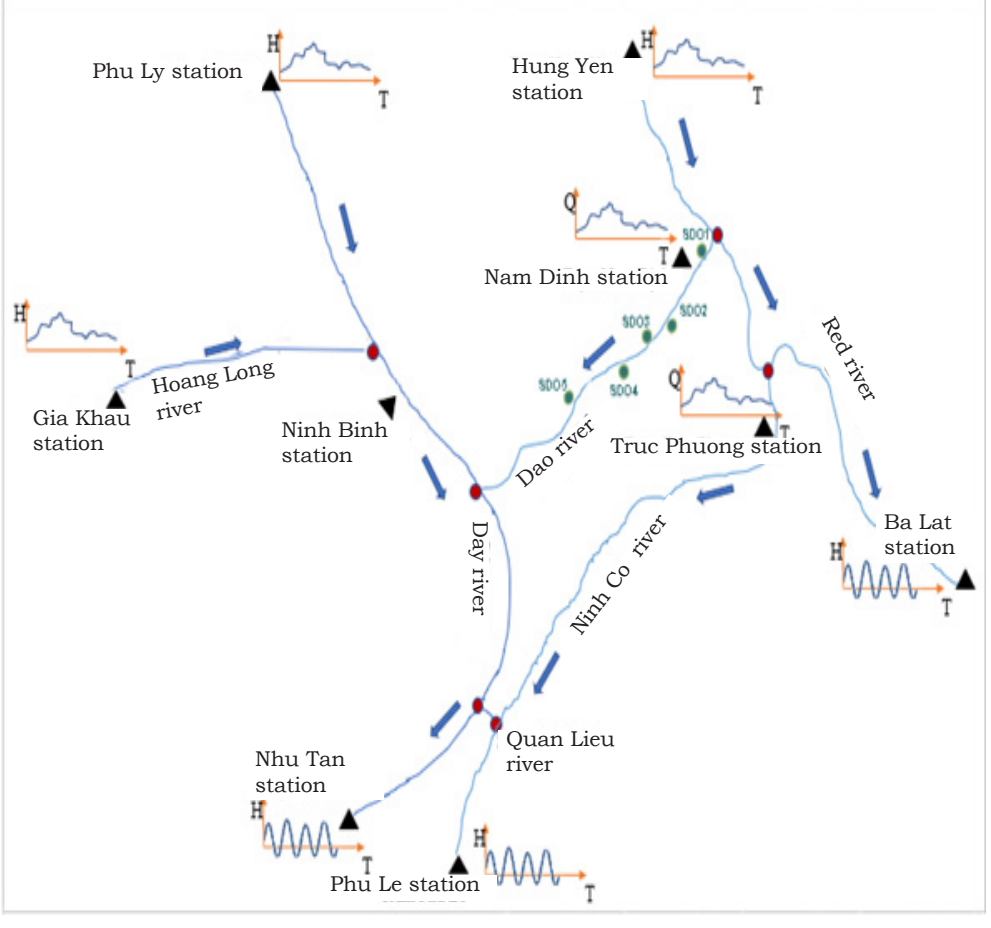
Water quality boundary conditions: In the study, a number of water quality investigation and survey locations along the Dao river were used as boundary conditions for the water quality model. Specifically, positions like Table 2.

Table 1. Boundary conditions in Hydraulic Models MIKE 11

No.	Station, location	River branches	Boundary type	Boundary form
1	Hung Yen	Hong	H~t	Upper boundary (Actual measured)
2	Phu Ly	Day	H~t	
3	Gian Khau	Hoang Long	H~t	
4	Ba Lat	Hong	H~t	Lower boundary (Actual measured)
5	Phu Le	Ninh Co	H~t	
6	Nhu Tan	Day	H~t	
7	Nam Dinh	Dao	Q~t	Calibration and verification

Table 2. List of Dao river water quality boundaries in the MIKE11 Model

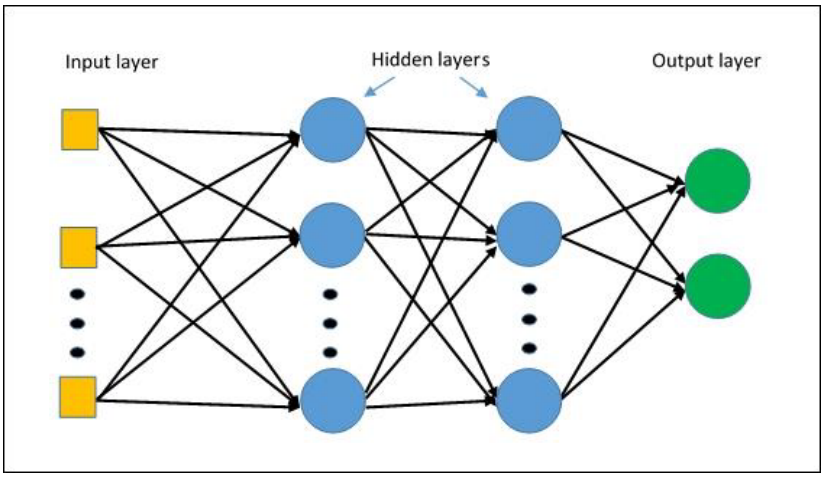
No.	Observation location	Section location in the MIKE11 model	Boundary form
1	SDO1	500	Calibrate, water quality testing
2	SDO2	7089	
3	SDO3	9913	
4	SDO4	13079	
5	SDO5	21723	



▲ *Figure 3. Calculated boundary diagram used in the MIKE 11 hydraulic model*

2.2. Model AI

Models are built from AI algorithms by processing data to make predictions. The process of processing data in the model is to determine parameters, which are closely related to the data including in the model. Meanwhile, the validation process will evaluate the reliability of the model. Algorithms are selected in each respective model to find the model suitable for the research. Select the appropriate optimization method in the model with the purpose of increasing the accuracy of the model. The parameters in the model will be determined by calculation and trial and error. Adjust the model parameters for the area so that the calculated results match the actual measured data. Use the correlation coefficient (R2) to evaluate the effectiveness of the AI Model compared to the results from the MIKE 11 Model. This index reflects the level of explanation of the independent variables for the dependent variable in the regression model regulation (Chena, Y.H; Chang, F.J, 2009).



▲ *Figure 4. Illustration of Multilayer Perceptron (ANN-MLP) regression network: Input layer, Output layer and Hidden layers*

Model data includes processing and testing data, divided at a rate of 90% data used for processing, 10% data used for testing. Before being fed into the AI model to process and make predictions, the data set will be analyzed by principal components PCA to find components that have good correlation with the model. For each water quality component at each point, a separate set of processing data is found after eliminating parameters with low correlation. Outlier removal is performed by the Standard Scaler method based on unit variance.

The adjusted parameters of the MLP multi-layer recurrent neural network include: hidden layer sizes (number of hidden layers), activation (activation function), solver (optimizer), learning rate. Using trial and error method, the research determined these parameters as follows: the number of hidden layers is set to 100, the activation function is relu function, the optimizer is adam, the learning rate is constant (Pham,Q.B.; Abba, S.I. et al., 2019).

The AI model requires a large amount of data to process and test the model, while the measurement data series on the Dao river is relatively short, not enough to build a reliable AI model. Therefore, the research will use the MIKE 11 model to run the model with different scenarios to create a data set for the AI model. In the AI model, input variables include: flow, BOD5, DO, Ammonia, Nitrate at the monitoring location of Hung Yen, Phu Ly. Simulated variables include: BOD5, DO, Ammonia, Nitrate concentrations at control locations Phu Le, Nhu Tan and Nam Dinh. The study created a series of input data for simulation variables according to the following principles:

The water quality parameters BOD5, Ammonia, Nitrate are randomly generated in the range from the lower bound value which are the quality indicators for column B of QCVN 08:2023/BTNMT (qualified for irrigation purposes, irrigation) and the upper limit is the value twice the current pollutant content.

The DO parameter fluctuates randomly within the upper limit which is the value in column B1 of QCVN 08:2023/BTNMT and the lower limit is half the DO value at the present time.

Temperatures at all waste sources are randomly generated within the range 15-35^{0}C

River water flow, research examines changes in water flow at the borders of Ninh Binh and Hung Yen. The randomly generated flow ranges from 3-7 m3/s at day dam, while this value ranges from 5-60 m3/s at the Nam Dinh monitoring gate location. Water quality factors at these two boundaries are kept constant as current conditions.

To obtain a large enough database, the study randomly generated a data series of 6872 data (hydrological data, water quality variables: temperature, BOD5 concentration, Ammonia, Nitrate, DO) with the step time is 1 day. Except for these adjustment positions, other positions were not considered in this study.

3. RESULTS AND DISCUSIONS

3.1. Results of water quality simulation using MIKE 11 model

The model was calibrated in 2 steps with 2015 hydrological data by changing parameters in the model (Manning roughness coefficient in the HD module and diffusion coefficient in the AD module) until the model results were consistent with actual measurement results. Then the model was tested using the 2016 database.

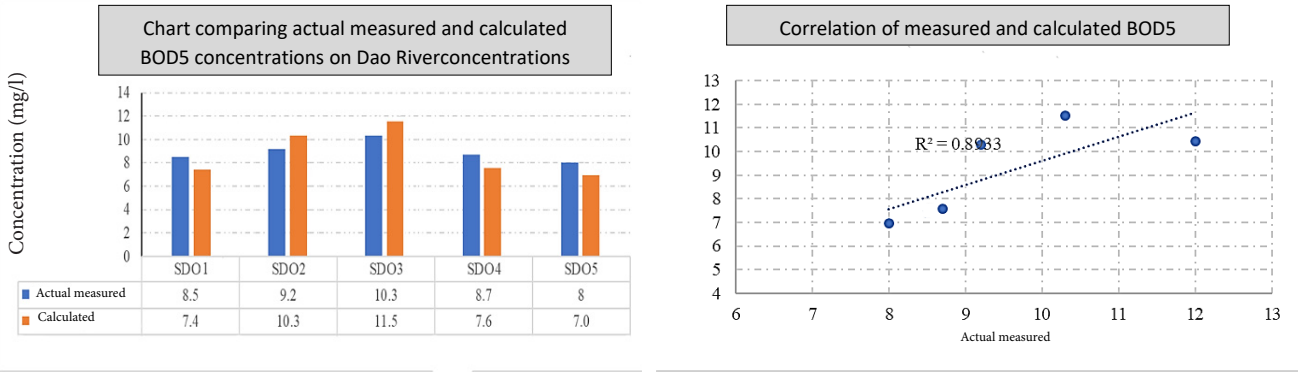
Calibrate the HD model through changing the manning roughness system in the range of 0.03-0.018.

Figure 4 and Figure 6 show the results of water quality calibration at the monitoring locations. The results show that the model results agree with the actual measurements in both values and trends.

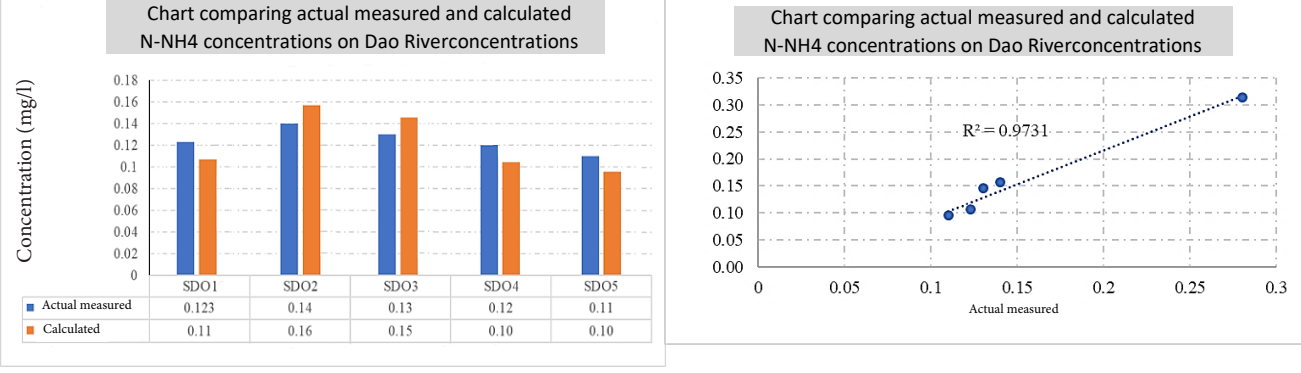
With the set of parameters of the MIKE 11- HD Model, along with water quality data, the study calibrated the MIKE11-ECOLab model for Dao river water quality in Nam Dinh province, the results are as follows:

Table 3. Parameter set for Water Quality Model

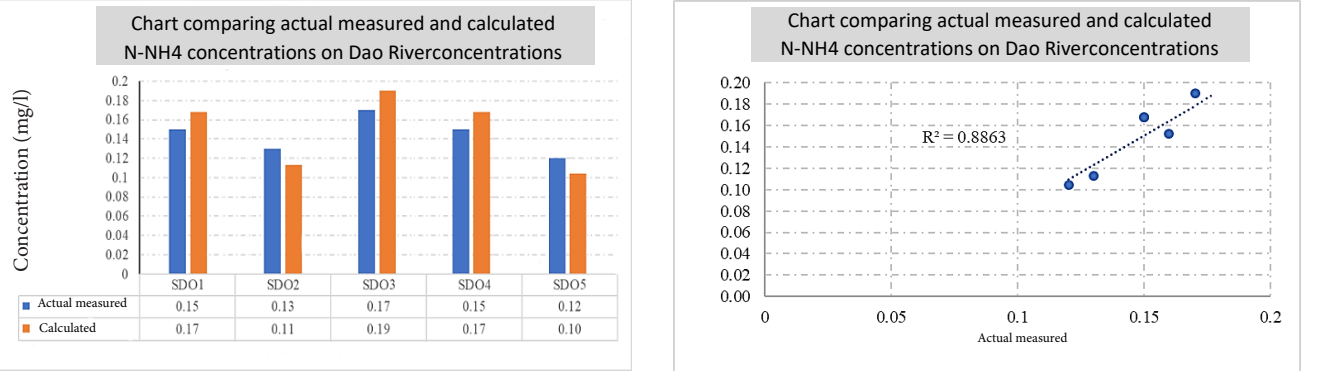
No	Some parameters of the Model ECOLab	Default	Calibrate
1	Oxygen consumption rate of animals and plants in water	3	3
2	Ate of maximum photosynthetic oxygen intake	3,5	40
3	Decomposition rate at temperature 20°C	0,5	0,5
4	Temperature coefficient for decay rate	1,02	1,02
5	N-NH4 conversion rate from BOD_5 decay	0,29	0,5
6	Ammonia decay rate in 20°C	1,54	0,3
7	Coliforms decay rate	0,7	0,01
8	P-PO_4 conversion rate from decay BOD_5	0,009	0,6
9	Decay constant for phosphorus particles	0,1	0,05



▲ *Figure 5. Comparison of results of adjusting BOD_5 concentration values actually measured and calculated from the model at monitoring points in 2017*



▲ *Figure 6. Comparison of calibration results of N-NH_4^+ concentration values actually measured and calculated from the model at monitoring points in 2017*



▲ *Figure 7. Comparison of correction results of P-PO_4^{3} concentration values actually measured and calculated from the model at monitoring points in 2017*

The MIKE 11-HD model simulates well the hydraulic flow on the river network system in Nam Dinh province and surrounding areas, the Nash index at Nam Dinh station is very high (from 0.92 to 0.98), the total error fluctuates between 5%÷10%, which means the simulation quality is satisfactory.

The MIKE 11-AD and MIKE - ECOLab models also simulate well the evolution of Dao river's water quality with relatively high Nash criteria (from 0.81 to 0.97), and the value error is less than 5%, this proves that The MIKE11-AD and MIKE – ECOLab models ensure reliability in simulating Dao River water quality.

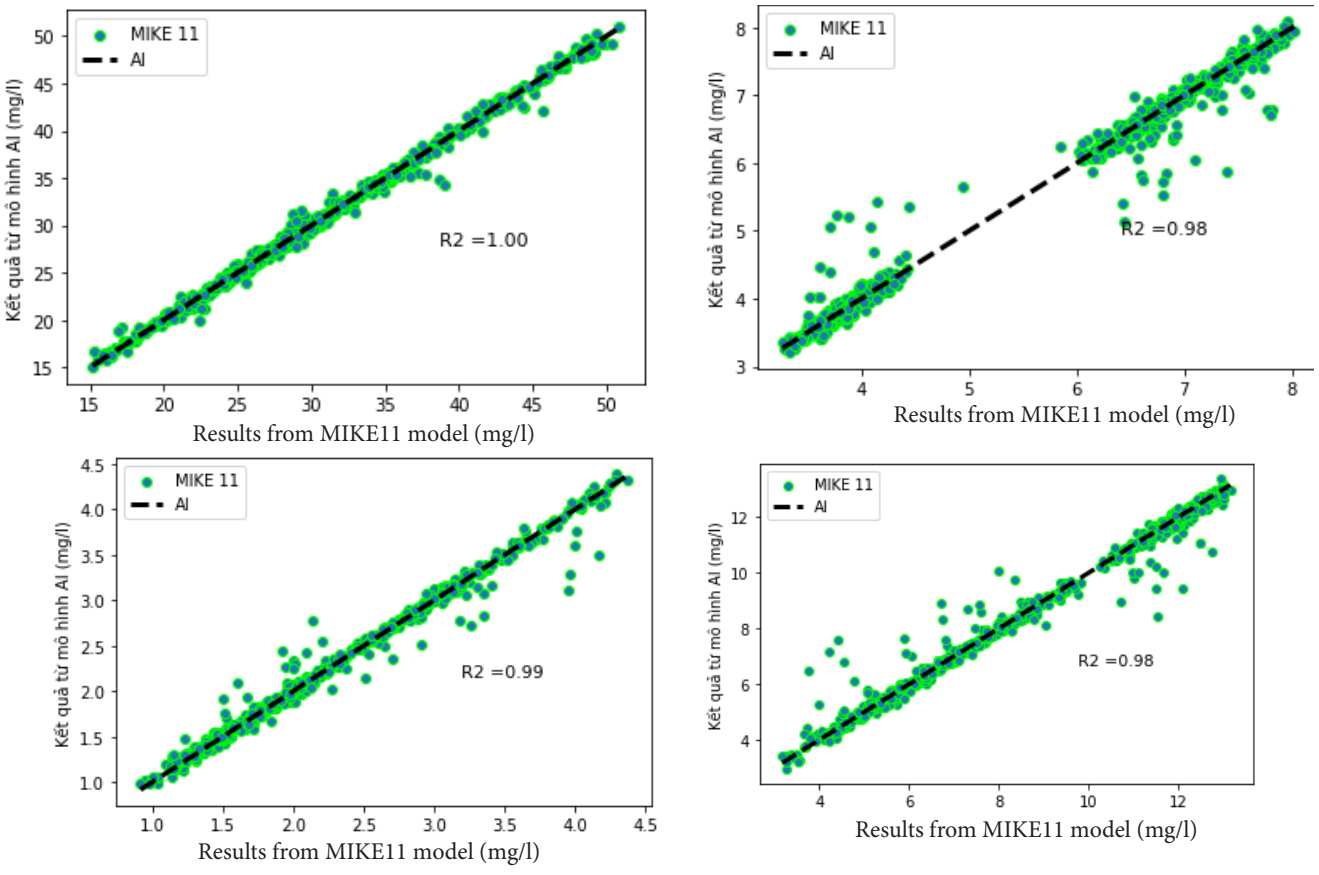
3.2. Results of water quality simulation using AI model

The processing of input data is evaluated by the correlation coefficients R2, which represents the reliability of the processing results from the AI model in research (ANN–MLP). Besides, the level of reliability is also evaluated through the Nash index (NSE). Simulation model calculated at locations: Hung Yen, Phu Ly, Gian Khau and Ba Lat, Phu Le, Nhu Tan, Nam Dinh Table 1, Figures 7, 8 present the results of testing the AI model corresponding to this parameter.

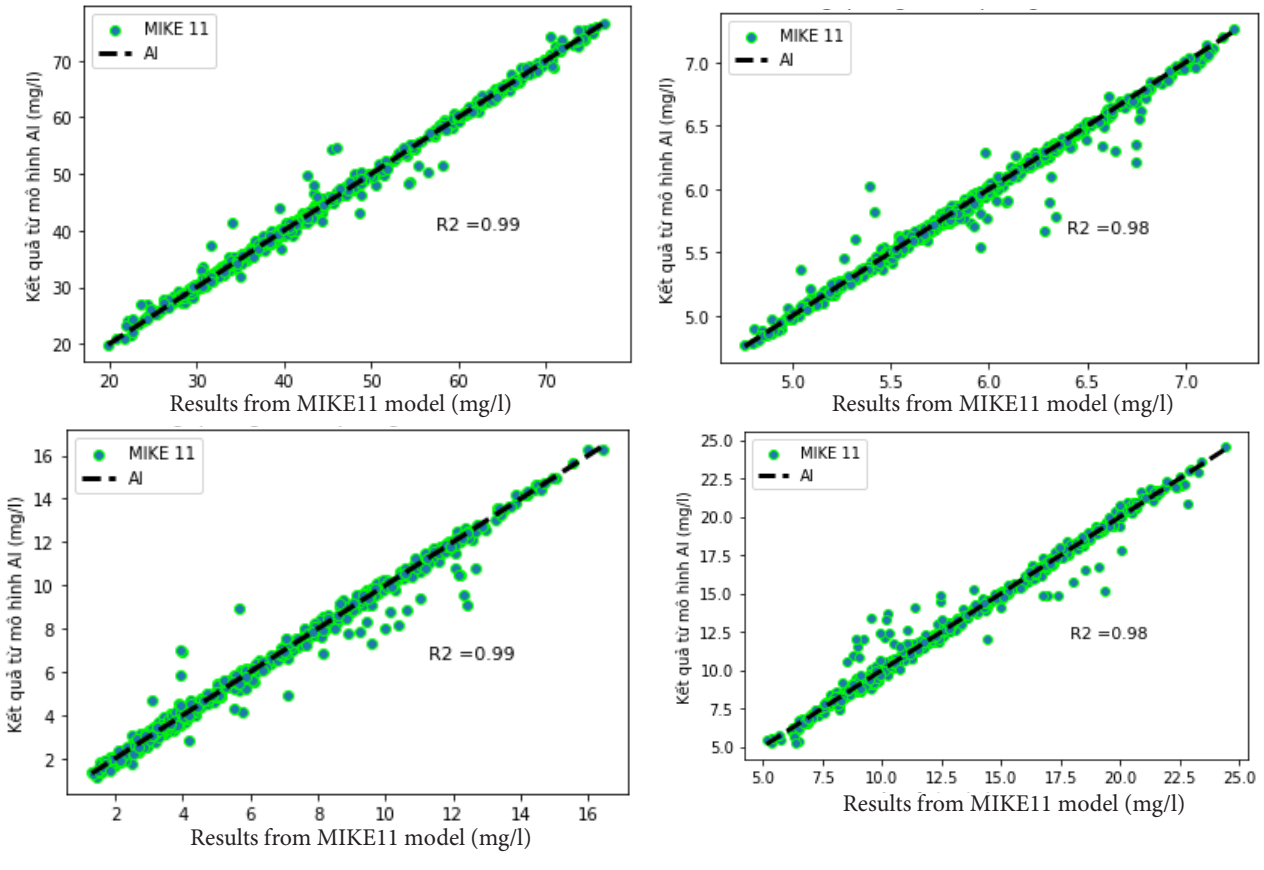
If the variation due to the residual is smaller, that is, the distance from the observation points to the regression estimate line is smaller, the variation due to regression will be higher, and then the R2 value will be higher. The results obtained from data processing at all stations reached R2 values from 0.98 to ~1, showing that the prediction ability of the AI model is close to the results from the MIKE11 model. Index NSE also achieved high reliability results from 0.96 to 0.99 respectively.

Table 4. Correlation coefficient between R^2 of NSE index comparing results from MIKE 11 Model and AI Model

Location	BOD_5		DO		NH_4^+		NO^{3-}	
	R^2	NSE	R2	NSE	R2	NSE	R2	NSE
Hung Yen	~1,00	0,98	0,98	0,98	0,98	0,98	0,98	0,96
Phu Ly	0,99	0,99	0,98	0,98	0,97	0,97	0,98	0,98
Gian Khau	0,98	0,97	0,99	0,99	0,98	0,99	0,98	0,99
Ba Lat	~1,00	0,98	0,98	0,98	0,99	0,98	0,98	0,97
Phu Le	~1,00	0,98	0,99	0,99	0,99	0,96	0,99	0,99
Nhu Tan	0,99	0,99	0,98	0,98	0,98	0,98	0,98	0,98
Nam Dinh	0,99	0,98	0,98	0,99	0,99	0,98	0,98	0,99



▲ *Figure 8. Correlation between simulation results from MIKE 11 model and AI at Nhu Tan point: (a) BOD_5 concentration; (b) DO concentration; (c) NH_4^+; concentration; (d) NO^{3-}concentration*



▲ *Figure 9. Correlation between simulation results from MIKE 11 Model and AI at Nam Dinh site: (a) BOD5 concentration; (b) DO concentration; (c) NH4+ concentration; (d) NO3–.concentration.*

With results considered reliable, the AI model allows forecasting water quality of the Dao river surface in different scenarios.

4. CONCLUSION

The results of this study show that the method of using the MIKE11 model combined with the AI model simulates river water quality relatively accurately. The AI Multilayer Perceptron regression network (ANN-MLP) model has been applied to simulate BOD_5, DO, Ammonia, Nitrate concentrations in Dao river. The results obtained from data processing at all stations achieved an R2 index from 0.98 to ~1, showing that the AI model's predictive ability is close to the results from the MIKE 11 model. AI model allows simulation of surface water quality on the Dao river instead of the MIKE11 model, and is the basis for building a model to predict river surface water quality for future scenarios. This is a tool to perform forecasts at a fast speed, convenient for research, simulation, forecasting and monitoring of water quality.

Thus, through water quality simulation using the MIKE11 model and the AI model, it has been assessed that the water quality situation on the Dao river is generally still in good condition, with the ability to receive additional waste sources if the waste sources are cleared and treated before discharge into the environment. However, with the current rapid economic development in Nam Dinh province, followed by the discharge of domestic and production water into the Dao river, the risk of water pollution is increasingly evident. Therefore, to minimize the risk of pollution and protect Dao river water quality, Nam Dinh province needs to plan and gradually invest in the construction of centralized urban wastewater treatment works for the urban area of Nam Dinh city to reduce the amount of pollutants in domestic wastewater flowing down the river and canal system surrounding the city into the Dao river.

To further perfect this model, in addition to the results already achieved, it is necessary to continue to simulate other water quality parameters: Phosphorus, Coliform, Ecoli, from which a more accurate and general assessment of water quality can be achieved river water quality. At the same time, it is possible to expand and develop further research on forecasting and controlling water quality pollution sources for the Dao river water source in particular and the river system in general using this model ▪

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Regulations on sea encroachment activites New Government Decree

HOÀNG NHẤT THỐNG
Ministry of Natural Resources and Environment

The Government has issued Decree No. 42/2024/NĐ-CP dated 16 April 2024 on sea encroachment activities. Accordingly, the sea area identified for sea encroachment must have its specific location, area, boundaries, coordinates in accordance with legislations on survey and mapping.

PROVISIONS ON LAND USE MASTER-PLANNING AND PLANNING FOR SEA AREAS IDENTIFIED FOR SEA ENCROACHMENT

The Decree clearly states: The sea area identified for sea encroachment must have its specific location, area, boundaries, coordinates in accordance with legislations on survey and mapping. Identifying sea areas for sea encroachment and inclusion in land use master-plan and plan must ensure principles specified in Points a, b and d, Clause 2, Article 190 of the Land Law 2024.

The Provincial People's Committee identifies, includes sea areas for sea encroachment activities in the land allocation and zoning plan according to functional areas and land types to each district administrative unit of the provincial master-plan, provincial land use plan, district land use master-plan, district land use plan.

In case the sea area identified for sea encroachment is already in the provincial master-plan or construction master-plan or urban master-plan (except for the case specified in Clause 5, Article 40 of the Land Law 2013) but not yet in the district land use master-plan, the Provincial People's Committee shall direct and include it in the district land use master-plan and annual district land use plan.

In case the sea area identified for sea encroachment is not included in the provincial master-plan, the Provincial People's Committee shall direct the District People's Committee to prepare, adjust and supplement the district land use master-plan and annual district land use plan.

Investment projects with sea encroachment activities have had document approving the implementation of the project with sea encroachment activities from a competent state agency in accordance with legislations before the effective date of this Decree (16th April 2024), the area of the sea area identified for sea encroachment will be included in the total area of the administrative unit; after completing sea encroachment, the area of land types will be supplemented with land use criteria according to the land use purpose stated in the investment project with sea encroachment activities in the provincial master-plan and district land use master-plan those have been allocated.

DECISION ON INVESTMENT POLICY, APPROVAL OF INVESTMENT POLICY, SELECTION OF INVESTORS FOR INVESTMENT PROJECTS WITH SEA ENCROACHMENT ACTIVITIES

The Decree stipulates that the approval of investment policy and decision on investment policy for investment projects with sea encroachment activities shall be carried out in accordance with legislations on investment, public investment, investment in the form of public-private partnerships.

The selection of investors to implement investment projects with sea encroachment activities having capital sources outside the state budget is carried out in accordance with legislations on investment, bidding, land, and investment in the form of public-private partnerships.

Sea encroachment activities in investment projects with sea encroachment activities established as sea encroachment investment projects or sea encroachment items of investment projects are implemented according to provisions of Article 6 of this Decree.

LAND ALLOCATION, LAND LEASE, SEA AREA ALLOCATION FOR SEA ENCROACHMENT

The Decree stipulates that for sea encroachment investment projects or investment projects with sea encroachment items funded by public investment capital, the order and procedures for land allocation and land lease shall comply with provisions in Clause 3, Article 68 of Decree No. 43/2014/NĐ-CP dated 15th May 2014 of the Government detailing the implementation of a number of articles of the Land Law.

In case a sea encroachment investment project or an investment project with sea encroachment items develops the land fund, after completing the sea encroachment and being accepted according to regulations, the investor of the sea encroachment project must hand over the entire encroached land and construction works (if any) to competent state agencies to allocate and lease land to organizations and individuals for use in accordance with legislations on land.

For a sea encroachment investment project or an investment project with sea encroachment items funded by state capital but not public investment and a project using other capital sources, the order and procedures for land allocation and land lease are as follows:

a. In case of land allocation, land lease through auction of land use rights, follow the order and procedures specified in Clause 5, Article 68 of Decree No. 43/2014/NĐ-CP dated 15 May 2014 of the Government detailing the implementation of a number of articles of the Land Law and Clause 21, Article 1 of Decree No. 148/2020/NĐ-CP dated 18 December 2020 of the Government amending and supplementing a number of decrees detailing the implementation of the Land Law;

b. In case of land allocation, land lease with selecting an investor through bidding according to legislations on bidding or in case of approval of the investor according to provisions of Clause 3, Article 29 of the Law on Investment 2020, follow the order and procedures for land allocation and land lease specified in Clause 3, Article 68 of Decree No. 43/2014/NĐ-CP dated 15 May 2014 of the Government detailing the implementation of a number of articles of the Land Law;

c. In case of land allocation, land lease not through auction of land use rights, follow the order and procedures specified in Clause 3, Article 68 of Decree No. 43/2014/NĐ-CP dated 15 May 2014 of the Government detailing the implementation of a number of articles of the Land Law.

The Decree clearly states: An investor of a sea encroachment investment project or an investment project with sea encroachment items when submitting dossiers for land allocation, land lease, sea area allocation must submit together with sea encroachment investment project or sea encroachment items of the investment project that has been approved by competent state agencies.

The Provincial People's Committee decides to allocate and lease land at the same time as allocating the sea area for sea encroachment. Investors of sea encroachment investment projects or investment projects with sea encroachment items do not have to pay fees to use the sea area to implement sea encroachment activities.

ACCEPTANCE OF COMPLETED SEA ENCROACHMENT

The Decree stipulates that the acceptance of completed sea encroachment is carried out for all or part of the completed sea encroachment area according to the progress of the sea encroachment investment project or the sea encroachment items of the approved investment project.

Examination of acceptance of completed sea encroachment is prescribed as follows:

a. Specialized agencies under the Provincial People's Committee carry out examination of acceptance of works of sea encroachment investment projects or sea encroachment items of investment projects. The order and procedures for examination of acceptance of completed sea encroachment works are carried out in accordance with legislations on construction;

b. The investor of a sea encroachment investment project or an investment project with sea encroachment items shall send a written request to specialized construction agencies under the Provincial People's Committee to examine the acceptance of all or each completed area of sea encroachment according to the progress of the sea encroachment investment project or sea encroachment items of the investment project already approved;

c. Within 60 days from the date of receipt of the written request, specialized construction agencies under the Provincial People's Committee shall examine the acceptance of the completed sea encroachment.

IDENTIFICATION OF LAND USE LEVY AND LAND RENTAL

Identification of specific land prices to calculate land use levy and land rental is carried out in accordance with legislations on land. In case the residual method is applied to identify specific land prices, the estimate of total development costs must include sea encroachment costs approved by competent state agencies according to provisions of Article 6 of this Decree; In case the total development costs are greater than the total development revenue, the difference is included in the costs of the sea encroachment investment project or investment project with sea encroachment items.

Within no more than 180 days from the date of completion of sea encroachment, the investor of a sea encroachment investment project or an investment project with sea encroachment items must prepare a dossier requesting settlement of sea encroachment costs and send to specialized construction agencies under the Provincial People's Committee for appraisal.

Within no more than 90 days from the date of receiving complete dossiers requesting settlement from the investor of a sea encroachment investment project or an investment project with sea encroachment items, specialized construction agencies under the Provincial People's Committee settle sea encroachment costs and submit them to the Provincial People's Committee for approval.

▲ *The sea area identified for sea encroachment must have its specific location, area, boundaries, coordinates in accordance with legislations on survey and mapping*

Handling the difference between settled costs of sea encroachment and costs of sea encroachment that have been included in total development costs when identifying specific land prices in case of applying the residual method (hereinafter referred to as the difference) is as follows:

- In case settled costs of sea encroachment are smaller than costs of sea encroachment included in total development costs, the investor must pay the difference;
- In case settled costs of sea encroachment are greater than costs of sea encroachment included in total development costs, the difference will be included in costs of the sea encroachment investment project or investment project with sea encroachment items.

ISSUANCE OF CERTIFICATES OF LAND USE RIGHTS, OWNERSHIP OF HOUSES AND OTHER ASSETS ATTACHED TO LAND

For land areas that are not part of the sea encroachment area, after the investor has fulfilled financial obligations on land, a Certificate of land use rights, ownership of houses and other assets attached to land will be issued.

For land areas formed from sea encroachment activities, the investor of the sea encroachment investment project or the investment project with sea encroachment items has completed financial obligations on land and received a notice of acceptance results of completed sea encroachment according to provisions of Article 8 of this Decree, a Certificate of land use rights, ownership of houses and other assets attached to land will be issued to the investor ▪

1. INTRODUCTION

Dead river is a concept that refers to rivers that are heavily polluted and unable to clean themselves, greatly affecting the lives of the community and socio-economic development in the river basin. Currently, three river basins have heavily polluted water environment including: Cau river, Nhue - Day river system, Dong Nai river. If there are no timely pollution treatment measures, in the future, water sources of these rivers cannot be used for production and daily life.

Causes of pollution are the failure to control waste from socio-economic development activities; not doing a good job of wastewater treatment; failure to separate rainwater and domestic wastewater in urban areas; population growth that leads to many consequences causing water pollution. People in riverside areas dump waste directly into the river, clogging the flow and declining river water quality to the point of being unusable. Therefore, improving, restoring, and reviving dead rivers is an urgent need of the community along these dead rivers in particular and of the country in general.

In Ha Noi, a number of projects have been and are being implemented to contribute to improving pollution such as drainage projects to improve the environment in phase 1 and phase 2, including: Renovation of the inner-city drainage system, renovation of the embankments and technical infrastructure along To Lich, Kim Nguu, Lu, Set rivers; renovation and dredging of inner-city lakes; wastewater treatment plants invested and put into operation: Kim Lien, Truc Bach, Bay Mau, Yen So. Although the goal of reviving "dead rivers" including To Lich, Nhue, Day, Tich, Kim Nguu, Lu, Set rivers has been of interest to Ha Noi many years ago through renovation schemes and measures to prevent pollution. However, the pollution level in 7 rivers is slowly improved, affecting the lives of people in the capital city. Currently, the State's resources to restore "dead rivers" are limited, therefore socialization and mobilization of organizations and individuals to participate in restoring "dead rivers" is necessary and feasible. Recognizing this, the Law on Water Resources (LWR) 2023 stipulates that "organizations and individuals are encouraged to participate in restoring degraded, depleted, and polluted water sources".

New points in the Law on Water Resources 2023: Encouraging organizations and individuals to participate in restoring "Dead rivers"

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Vietnam National Commission on Irrigation & Drainage

2. PROVISIONS ON SOCIALIZATION OF WATER SOURCE PROTECTION AND DEVELOPMENT

2.1. Provisions on socialization activities in the Law on Water Resources (LWR) 2023

Article 4 of the LWR 2023 clearly states that the State encourages organizations, individuals to participate in baseline survey activities; protect, develop water resources; restore degraded, depleted and polluted water sources; prevent, combat and overcome harmful effects caused by water. Organizations, individuals participating in restoring degraded, depleted, and polluted water sources will enjoy incentives and support according to the provisions of this Law and other relevant legislations (Point e, Clause 1, Article 35 of the LWR 2023).

In addition, the Law also encourages financial institutions to develop green credits, green bonds and financial products to support water resource restoration activities. According to Clause 4, Article 74 of the LWR, organizations, individuals participating in implementing projects with water resource restoration activities are entitled to the following incentives: Incentives, support, tax exemptions and reductions, and fees for water resource exploitation rights; guaranteed by the State to receive investment results; prioritized participation in providing public services ordered by the State; participation in bidding to receive contracts, projects using domestic and foreign capital sources in accordance with operational functions and tasks; organizations, individuals implementing projects in the form of public-private partnerships (PPPs) are guaranteed investment in the form of PPPs.

2.2. Provisions on socialization activities in a number of other legal documents

Currently, socialization is encouraged in many fields. It can be considered an inevitable trend for development and protection of natural resources. Resolution No. 39-NQ/TW dated 15 January 2019 of the Politburo on improving the efficiency of management, exploitation, use and promotion of the economy's resources also clearly identified the importance of diversifying resources and promoting socialization: "...diversify forms of resource mobilization and use; promote socialization and strongly attract non-state investment resources; apply market principles in managing, exploiting and using resources for development; amend, supplement and improve legislations, mechanisms and policies to maximum open up, unlock and improve the efficiency of using existing resources, in accordance with the socialist-oriented market economy". Accordingly, institutional and policy renovation towards socialization of the water sector is necessary and essential, making an important contribution to the management, protection and development of water resources through mobilizing capital and resources of organizations and individuals, reducing the burden on the State budget and ensuring that water resource policies are implemented effectively and synchronously. Regulate socialization policies to create a legal corridor for organizations, individuals participating in the above activities; develop transparent and clear policies, create favourable and attractive mechanisms and conditions to encourage investors to participate.

According to the Law on Natural Disaster Prevention and Control 2013, amended and supplemented in 2020, Article 5, the State's policy in natural disaster prevention and control stipulates: Encourage organizations, households, individuals to be proactive to implement measures to prevent and control natural disasters; encourage organizations, individuals to invest in construction, research and apply scientific, technological advances in natural disaster prevention and control activities. The State protects the legitimate rights and interests of organizations, individuals participating in natural disaster prevention and control; provides incentives and encourages insurance enterprises to conduct natural disaster risk insurance business; supports enterprises participating in investment in production, business in areas frequently affected by natural disasters according to the provisions of legislations on investment, enterprises and natural disaster prevention and control; supports for corporate income tax exemption and reduction policy for contributions to natural disaster prevention and control.

The Law No. 64/2020/QH14, investment in the form of PPPs stipulates: Investment in the form of PPPs is a form of investment implemented on the basis of time-limited cooperation between the State and private

▲ *To Lich river in Ha Noi*

investors through the signing and implementation of PPP project contracts with the aim to attract private investors to participate in PPP projects. Investment fields, scale and classification of PPP projects are: Irrigation; clean water supply; drainage and wastewater treatment; waste treatment. A PPP project is a collection of proposals related to investment to provide public products and services through the implementation of one or more of the following activities: Constructing, operating, trading infrastructure works and systems; renovating, upgrading, expanding, modernizing, operating, trading existing infrastructure works and systems; operating, trading existing infrastructure works and systems.

The main characteristics of these special partnerships are: (1) common interests between the public and private sectors; (2) reasonable risk allocation; (3) financial sustainability of the project; (4) reduction of the costs of infrastructure projects; (5) better conditions to access capital markets; (6) ensuring early termination of State capital, based on opportunistic criteria, or convenience level; (7) prohibition or limitation of the use of State power. Possible forms of PPPs are: DCM (design-construct-maintain), DCMO (design-construct-maintain-operate), BOO (build-own-operate), BOOT (build-own-operate-transfer), DBFO (design-build-finance-operate). Countries, depending on their actual conditions, apply one or several forms of PPPs.

In particular, the Law on Investment 2020, regarding the form of PPPs, stipulates State policies in irrigation activities (Article 4) such as: Provide tax incentives for organizations and individuals managing and exploiting irrigation works providing public irrigation products and services according to tax legislations; support organizations and individuals to invest in new construction, repair and upgrade small irrigation systems and in-field irrigation systems, advanced and water-saving irrigation systems, advanced and modern irrigation and drainage systems, wastewater treatment systems for reuse; support organizations and individuals providing irrigation products and services in the case of preventing, combating and overcoming the consequences of drought, water shortage, saltwater intrusion, desertification, floods, waterlogging, etc.

3. INADEQUACIES IN SOCIALIZATION POLICIES RELATED TO WATER RESOURCES

Obviously, through the process of implementing the LWR, the system of legal documents on water resources and related policies shows that it is basically consistent with socio-economic development practices of the country, creating a strong change in the society, raising awareness, responsibility and action of ministries, sectors, localities, organizations, individuals and people on water resource protection. However, in the actual implementation process, some shortcomings and limitations have been revealed such as: There are no specific regulations to implement socialization

policies in fields relating to water resources and environmental protection, irrigation, natural disaster prevention and control. Laws only generally support and prioritize socialization activities, but specifically how to support and prioritize is still unclear. Of course, Laws only provide general and directional information, but there is no Decree or Circular guiding the implementation of these activities. Mobilizing funds from the private sector for construction and upgrading of irrigation works, natural disaster prevention and control, wastewater treatment... still faces many difficulties because there is no attractive financial mechanism. On the other hand, due to not approaching water resource management to serve multiple goals, investment from the State budget is still limited.

Although socialization in the field of water resources has been mentioned in the LWR 2023, basically activities related to water resources are still mainly assigned to state management agencies and use funding from the state budget. Articles 26 and 27 of the Law stipulate that the responsibility for restoring depleted and polluted water sources is belonging to the Ministry of Natural Resources and Environment and the People's Committees of the provinces. However, currently, there is a lack of monitoring information, data on the quantity and quality of water sources, and baseline survey data for state management of water resources and support for decision-making, degradation, depletion, and pollution of rivers are emerging problems that need to be resolved soon and thoroughly...

4. SOLUTIONS TO EFFECTIVELY IMPLEMENT SOCIALIZATION OF THE WATER SECTOR

Firstly, to ensure meeting the requirements for sustainable management, exploitation, use and protection of water resources in the face of the actual conditions of the country's limited resources today and in the next 10 years, especially with the outstanding development of digital technology platforms in the world, it is necessary to have the participation of organizations and individuals with economic resources, human resources, infrastructure, new technology that can meet increasing requirements in water resource governance.

Secondly, it is necessary to clarify a number of concepts related to socialization in water resource management and exploitation, environmental protection, natural disaster prevention and control... in the LWR, Law on Irrigation, Law on Environmental Protection; it is necessary to specifically stipulate what socialization resources include. Socialization content needs to be integrated into activities of water resource management and exploitation, environmental protection, natural disaster prevention and control... Socialization content is not new, many other sectors have applied it successfully such as the Education, Health... therefore, it is necessary to learn and gain experience in implementing socialization activities from these sectors.

Thirdly, when implementing socialization activities in fields related to water resources, environmental protection, natural disaster prevention and control, forest protection... it is necessary to carry out full and transparent accounting.

Fourthly, applying socialization activities requires creativity and learning from international experiences, for example socialization of water environmental protection abroad through the "River contract". River contract is an effective measure to restore, improve and conserve a river through signing contracts between state administrative agencies, water service providers, companies, and associations or other relevant organizations. An important point to emphasize is that the preparatory phase of the river contract involves the collection of all necessary technical information as well as the carrying out of studies, analysis and diagnosis of river basin conditions and problems that may occur.

Water resources provide important resources for humanity, both in terms of life benefits and water environmental value. It has very different characteristics from other natural resources: Water is necessary for life; water obeys hydraulic laws; water is very vulnerable. Therefore, exploiting, using effectively, protecting and developing natural resources is not the same as normal resources. Thus, implementing socialization policies for exploitation, use, protection and development of water resources must pay attention to these characteristics and must be under the management of the State; must comply with the State's water resource development master plans and plans. In particular, all socialization activities in the water sector need to meet the needs of socio-economic development but must be consistent with the socio-economic development master plans and plans of the region and the whole country.

With the change in policy mechanisms on socialization and financing of water resources in the LWR 2023, we hope to mobilize social resources to "join hands" to protect water resources in both quantity and quality, restore "dead rivers", ensure fairness in water exploitation and use for all sectors; improve the level of national water resource security, environmental protection, river ecosystems and cultural values associated with water of the Vietnamese people ▪

National environmental monitoring master plan for the period of 2021-2030 with a vision to 2050

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In Viet Nam, the environmental monitoring network was formed in the 90s of the last century after the first Law on Environmental Protection (LEP) was promulgated in 1993. On 7th March 2024, Deputy Prime Minister Tran Hong Ha signed Decision No.224/QĐ-TTg approving the National environmental monitoring master plan for the period of 2021-2030 with a vision to 2050. This is a specialized technical master plan, complementing previous provisions in Decision No.16/2007/QĐ-TTg and Decision No.90/QĐ-TTg to continue perfecting the national environmental monitoring network.

1. TOWARDS BUILDING A SYNCHRONOUS, MODERN NATIONAL ENVIRONMENTAL MONITORING SYSTEM

With the view that the planned national environmental monitoring network must comply with the provisions of the LEP, be consistent with the national planning system and the country's socio-economic development practices; ensuring monitoring of the baseline environment and impact environment in inter-regional, inter-provincial, and transboundary areas, contributing to assessing the load-bearing capacity of the environment, giving priority to improving national environmental warning and forecasting capacity. In particular, the national environmental monitoring network is planned on the basis of inheriting the contents of environmental monitoring in the national natural resources and environment monitoring network master plan for the period of 2016-2025 with a vision to 2030, with the integration between fields, while taking advantage of the existing technical facilities and monitoring teams, in particular, must overcome the inadequacies in previous master plans, further strengthen the advanced, modern monitoring tools, equipment, digital transformation and concentration of resources for processing and evaluating environmental quality monitoring data. This is an open system, regularly adjusted and supplemented to meet the requirements for monitoring data to serve the evaluation of environmental quality in inter-regional, inter-provincial, and transboundary areas.

In order to build a synchronous, advanced and modern national environmental monitoring system, monitoring key areas of inter-regional, inter-provincial, transboundary nature, areas with many sources of waste and monitoring biodiversity in nature reserves, biodiversity corridors, and high biodiversity areas; strengthen connectivity with provincial environmental monitoring systems; ensure monitoring of environmental quality developments; meet the requirements of providing, announcing, and publicizing environmental monitoring information and data and improving capacity for environmental warning and forecasting, the Ministry of Natural Resources and Environment has submitted to the Prime Minister the National environmental monitoring master plan for the period of 2021-2030 with a vision to 2050 for approval.

According to the master plan, the period of 2021-2030 will maintain 19 continuous automatic air quality monitoring stations that have been in operation; complete investment and installation of 18 continuous automatic air quality monitoring stations being deployed at monitoring locations inherited from previous master plans; continue to invest and add new ones to complete 31 continuous automatic air environment monitoring stations across the country, including 6 continuous automatic monitoring stations of baseline air quality in 6 socio-economic regions; establish and complete a continuous automatic monitoring network of inter-provincial river and lake water environmental quality at upstream locations, across borders and bordering locations between provinces; develop periodic surface water quality monitoring networks in the main streams of inter-provincial rivers and lakes that play an important role in socio-economic development and environmental protection. At the same time, maintain and expand monitoring at river estuaries and coastal points according to previous master plans; establish a sea water quality monitoring network in sea areas under Vietnam sovereignty, sovereign rights and jurisdiction in accordance with the legislation of Vietnam; invest, upgrade and modernize existing laboratories and environmental quality monitoring stations; complete investment and construction of a laboratory under the Environmental

Monitoring Station of the Southeast region; design and build the national environmental monitoring information and database system, integrate the entire environmental quality monitoring data system into a common system across the country...

Objectives of the master plan to 2050: Increase investment, expand continuous automatic air quality and water quality monitoring stations, apply new monitoring technology towards gradually replacing periodic air and surface water quality monitoring points by continuous automatic air quality and water quality monitoring stations; organize to conduct biodiversity monitoring in biodiversity corridors and high biodiversity areas established. In addition, by 2050, will research and apply modern information processing technologies, models using artificial intelligence, and comprehensively deploy digital transformation models in environmental monitoring data management and analysis for environmental quality forecasting activities; strengthen socialization work for the implementation of the master plan, develop priority mechanisms, encourage organizations and individuals to invest in continuous automatic environmental quality monitoring stations and participate in the periodic environmental monitoring programs to take advantage of resources and facilities of units outside the State.

2. ENVIRONMENTAL MONITORING NETWORK SYSTEM

The Master plan clearly indicates the location of points, forms and frequency of monitoring.

For the air quality monitoring network: Continue to maintain and expand the ambient air quality monitoring network at 216 air quality monitoring points on the basis of continuing to maintain monitoring at 106 points already established in the previous planning period and expanded to new 110 air quality monitoring points. Among 216 planned points, there will be 103 monitoring points being implemented, 98 monitoring points planned to be implemented in the period of 2021-2030 and 15 continuous automatic air quality monitoring stations newly built after 2030. At the same time, expand and build 68 continuous automatic air quality monitoring stations with 6 baseline air quality monitoring stations and 62 impact air quality monitoring stations. Baseline air quality monitoring stations representing 6 socio-economic development regions are located in 6 localities including: Lai Chau, Hai Phong, Quang Nam, Dak Nong, Dong Nai and Dong Thap. *For the periodic air quality monitoring points:* Carry out impact monitoring at 148 monitoring points focusing on provinces/cities in regions and cities with important socio-political significance.

For the surface water quality monitoring network: Continue to maintain and expand the surface water quality monitoring network at 499 surface water quality monitoring points on the basis of continuing to maintain monitoring at the 368 points already in the previous master plans and expanded to 131 new surface water quality monitoring points. Of the 499 planned surface water quality monitoring points including 260 monitoring points being implemented, 216 monitoring points planned for implementation in the period of 2021-2030, 23 new continuous automatic surface water quality monitoring stations will continuously be built after 2030; expand and build 59 continuous automatic surface water quality monitoring stations with 6 baseline monitoring stations and 53 continuous and impact monitoring stations, using 4 continuous automatic surface water quality monitoring stations for the purpose of monitoring transboundary impacts; carry out impact monitoring at 440 monitoring points on the main stream of large rivers, inter-provincial, transboundary rivers with important socio-political significance...

For the coastal sea water quality monitoring network: Continue to maintain and expand the coastal sea water quality monitoring network at 70 monitoring points on the basis of continuing to maintain monitoring at the existing 43 points and 27 new additional monitoring points planned for the period of 2021-2030. For continuous automatic sea water quality monitoring stations: Add to the master plan 6 continuous automatic coastal sea water quality monitoring stations operation in the coastal areas of Ha Tinh, Quang Binh, Quang Tri and Thua Thien - Hue; carry out impact monitoring at 64 periodic coastal surface water quality monitoring points in coastal provinces; continue to maintain integration of coastal sea water monitoring with 6 existing oceanographic monitoring stations.

In addition, based on the objectives of the monitoring program, monitoring parameters and frequency are encouraged to be expanded to increase the thickness of the monitoring data series, ensuring good service for state management of environmental protection, environmental quality warning and forecasting. The master plan also points out the network of units carrying out monitoring and the development orientation is to focus on investing and upgrading the system of advanced and modern laboratories with full capacity and resources to carry out implementation of national environmental monitoring programs.

3. MAJOR SOLUTIONS TO IMPLEMENT THE MASTER PLAN

Firstly, developing *solutions on legal policies and strengthening organizational structures:* Complete and promulgate synchronous environmental monitoring processes, norms and targets, meeting the practical requirements of the field of environmental monitoring; develop policies to strengthen socialization of environmental monitoring, mobilize the participation of social resources to invest in the implementation of the national environmental monitoring network; develop regulations on economic-technical norms for environmental monitoring activities in accordance with the current state of socio-economic development; review and develop additional standards to guide technical methods for implementing environmental monitoring activities; strengthen the organizational structure, staffing and complete the functions and tasks of units in the environmental monitoring network to ensure the implementation of the master plan.

Secondly, strengthen research and application of science and technology for environmental monitoring activities: Increase the application of automatic monitoring technology and equipment to meet technical requirements to supplement the environmental monitoring network, improve the capacity to process and store environmental monitoring data to create data application effectiveness; promote technical facilities, field equipment, tools, and technology to serve biodiversity monitoring activities; prioritize geographic information systems, maps and remote sensing images, camera traps, sound traps, satellite positioning devices... and new technology solutions in smart receiving, transmitting and processing data to optimize transmission, exploitation, and use of biodiversity monitoring data...; research and apply new monitoring technology in the direction of using mobile monitoring devices attached to vehicles moving on rivers and at sea to monitor water quality...

Thirdly, promote investment and mobilize financial resources: Investment in construction and equipment - mobilize maximum financial resources from economic sectors to invest in modern technical facilities and equipment,

▲ *Automatic air quality monitoring station in Quang Nam*

technology for environmental monitoring activities. The network of continuous automatic monitoring stations needs to continue to be expanded and invested according to the new master plan to ensure the density of monitoring data transmitted to the national data network to meet the requirements of timely warning and forecasting developments in environmental quality; arrange funding for investment in infrastructure/ software networks to connect, transmit/receive, process, and manage data.

Fourthly, expand international cooperation: Cooperate with international research organizations and monitoring networks to bring programs of exchanging experiences, monitoring information, and data according to international standards on performing environmental analysis into contents related to implementing environmental monitoring planning, for example, East Asia acid rain monitoring network, clean air network, transboundary pollution monitoring programs (water, air...); promote, prioritize the development and implementation of scientific research and international cooperation programs and projects to mobilize resources and experiences for biodiversity monitoring; continue to expand international cooperation in the fields of environmental monitoring technology, technique research, improvement with experienced organizations in the region and advanced countries.

Fifthly, strengthen training: Recruit, train and retrain domestically and abroad to build a team of highly specialized monitoring and analysis staff, ensuring a successor workforce; research and innovate the environmental monitor training program in a selective manner, ensuring that trained monitors can perform many types of monitoring, with some receiving specialized training as technicians; promote retraining to improve the professionalism and skills of existing staff, technicians and monitors with focus on improving the practical capacity of monitors to meet the operating requirements of each monitoring station and point and the entire network... ▪

Technical guidelines for conducting environmental audit in Vietnam

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Conducting environmental audit is considered an effective environmental management tool for production enterprises. In addition, environmental audit is also considered a reliable information channel, providing management agencies with information on the environmental management situation of enterprises. In Vietnam, although environmental audit has been conducted by a number of organizations and units, there is currently no general technical guidelines as a reference document. Therefore, in some cases, key contents of environmental audit are being integrated into financial audits or inspection and examination processes.

Article 74 of the Law on Environmental Protection (LEP) 2020 stipulates that environmental audit includes two main contents: (1) auditing the use of energy, chemicals, raw materials, and scraps imported from abroad as raw materials for production; (2) auditing the pollution control and waste management. Through studying the concepts, characteristics, classification of environmental audit as well as technical guidelines for conducting environmental audit of some countries, it is shown that the first content about auditing the use of energy, chemicals, raw materials, and scraps imported from abroad as raw materials for production is the same as waste audit; the second content about auditing the pollution control and waste management is similar to the compliance audit. Therefore, this article proposes to develop technical guidelines for conducting environmental audit in Vietnam for two contents: waste audit and compliance audit.

1. INTRODUCTION

In fact, countries or some international organizations, when developing technical guidelines for conducting environmental audit, only focus on one specific content such as waste audit or compliance audit. A number of popular technical guidelines that have been issued such as: Guidelines for conducting waste audit of UNIDO and UNEP; Guidelines for waste audit in pulp and paper industries of the Food and Agriculture Organization of the United Nations (FAO); Guidelines for waste audit; Compliance Audit Handbook of Australia; Guidelines for Compliance Audit of Malaysia…

Summary shows that the main and important contents of those documents are instructions on processes and methodologies for conducting audit. Basically, the processes for conducting waste audit and compliance audit are according to the processes for conducting environmental audit including 03 specific stages: pre-audit, on-site audit and post-audit. For each specific content of waste audit or compliance audit, the steps in each stage will have different instructions.

The LEP 2020 stipulates that conducting environmental audit needs to include both waste audit and compliance audit.

2. TECHNICAL GUIDELINES FOR CONDUCTING ENVIRONMENTAL AUDIT IN VIETNAM

2.1. Procedure for environmental audit

Technical processes for conducting environmental audit for production, business and service establishments have 03 stages and 10 steps. Details are shown in Figure 1.

Stage I: Pre-audit			
Step 1: Establish an audit team	Step 2: Identify goals and scope	Step 3: Develop an implementation plan	Step 4: Collect preliminary information

Stage II: On-site audit		
Step 5: Collect and synthesize information and data	Step 6: Analyze and evaluate information and data contents	Step 7: Provide audit findings

Stage III: Post-audit		
Step 8: Propose recommendations and remediation solutions	Step 9: Develop, complete the environmental audit report	Step 10: Develop an action plan

▲ *Figure 1: Detailed processes for self-conducting environmental audit at production, business and service establishments*

With instructions on waste audit, the guidelines need to focus on instructions on implementing material balance, including instructions on collecting information and data, using materials, electricity, water and output information such as main products, by-products, types of waste... at factories and production facilities; instructions on calculating material balance of each production process or stage.

With instructions on compliance audit, the important content is to develop a checklist, including a set of questions to collect information related to environmental management, evaluate the compliance with legal regulations on environmental protection of establishments based on evaluation criteria.

2.2. Tools and techniques

Some tools that can be used in environmental audit at companies and enterprises:

• Checklist: A very useful tool used to ensure that various contents or topics are covered during the audit. A checklist is useful in specialized cases where a complex set of issues and questions need to be asked to ensure nothing is overlooked.

• Questionnaires: Evaluation protocols or evaluation questionnaires provide the basis and structure for most evaluations. They are based on checklist questionnaires but are more complex and include more details, sometimes logistical information and data related to the evaluation and the location being evaluated.

• Interview: A method of checking information through interviewing relevant individuals. Interview is an integral part of an audit. Interview answers can provide auditors with information that auditors did not previously have or provide corroborating audit evidence.

• Observation: An important component of an evaluation test.

• Images: A very valuable aid during the audit process. However, to use this method, several important practical points must be kept in mind, the most important of which is official approval before using this technique.

• Sampling: Various sampling techniques such as random sampling, stratified random sampling, judgmental sampling, purposive sampling, etc., can be used during the evaluation process.

Besides the general technical tools mentioned above, depending on each type of environmental audit, a number of specialized technical methods can be applied. Specifically, for this type of waste audit, the material balance method is also applied. Material balance is an important tool for identifying losses and verifying quantitative data of input materials and output waste of the production process. Material balance must be carried out individually for all raw materials used and products, waste generated from the production process. When there is a chemical reaction taking place in a system, it is convenient to perform "elemental balance" for the chemical elements in a system. Material balance can assist in identifying the concentrations of waste components generated.

2.3. Report templates for self-conducting environmental audit at production, business and service establishments

In addition to the main contents introducing general information about the audited establishment, audit objectives, plans and methods, it is necessary to present the results of environmental audit of the establishment. Contents to be presented are as follows:

a) Results of collecting and synthesizing information, data

- General presentation of input information, data serving production activities at the production and business establishment.

- General presentation of output information, data at the selected production and business establishment, including:

b) Analysis and evaluation of the results of environmental audit

- Results of material balance implementation

- Results of evaluation of compliance with regulations on pollution control and waste management

c) Audit findings

- Problems found in the efficiency of using input materials, sources of waste generation and origin of waste generation.

- Problems found in the compliance and non-compliance with pollution control and waste management regulations.

d) Proposed action plan

- Action plan to minimize loss and waste of input materials and reduce waste generation.

- Action plan to achieve better compliance with pollution control and waste management regulations.

3. CONCLUSION

This article proposes processes, methodologies and report templates to conduct environmental audit according to the contents specified in Article 74 of the LEP 2020. The guidelines when issued, will help production, business and service establishments research, learn and apply environmental audit themselves, thereby helping environmental auditing tools be more widely spread and popularized and become an effective internal environmental management tool ■

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Promote the separation at source to optimize waste resources

In environmental protection work, separation at source of domestic solid waste at source is one of the urgent issues today. The Law on Environmental Protection No. 72/2020/QH14 (LEP) passed by the National Assembly on 17th November 2020, has 6 Articles stipulating the management of domestic solid waste, including the following contents: Separation at source, storage and transfer of domestic solid waste (Article 75); Aggregation points and transfer stations for domestic solid waste (Article 76); Collection and transport of domestic solid waste (Article 77); Treatment of domestic solid waste (Article 78); Costs of collection, transport and treatment of domestic solid waste (Article 79); Environmental remediation and improvement in domestic solid waste landfills (Article 80). These provisions guide how to manage and deal with waste; promote people to classify and minimize domestic solid waste generated at source, and at the same time, stipulate the responsibility of the Ministry of Natural Resources and Environment (MONRE), People's Committee at all levels, agencies, organizations, households and individuals in management of domestic solid waste.

SEPARATION AT SOURCE OF DOMESTIC SOLID WASTE ACCORDING TO THE LOCAL ACTUAL SITUATION

One of the new points of the LEP 2020 is to change the approach to waste management with a consistent view of considering waste as a resource; promoting separation at source of waste at source; orienting how to manage and deal with waste, contributing to promoting circular economy in Viet Nam towards the goal of bringing a clean living environment for sustainable development. Implementing Clause 5, Article 79 of the LEP, on 2nd November 2023, the MONRE issued Technical Guidance on separation at source of domestic solid waste in Official Dispatch No.9368/BTNMT-KSONMT to support People's Committee of provinces and centrally run cities to study and apply in the process of developing and promulgating detailed regulations on separation at source of solid waste appropriate to the actual situation in each locality.

The Guidance is developed basing on the perspective of ensuring the compliance with the LEP 2020, Decree No.08/2022/NĐ-CP dated 10th January 2022 detailing a number of articles of the LEP, Circular No. 02/2022/TT-BTNMT dated 10th January 2022 detailing the implementation of a number of articles of the LEP and other relevant legal documents, policies of the Party and State. The Technical Guidance provides maximum identification of all types of domestic solid waste generated during daily activities for local authorities to study and apply into regulations to ensure compatibility with local practice.

Clause 7, Article 75 of the LEP stipulates: The Vietnamese Fatherland Front Committee and socio-political organizations at all levels shall encourage residential communities, households and individuals to classify domestic solid waste at source; encourage rural households and individuals that generate domestic solid waste to classify, store and transfer domestic solid waste in accordance with regulations. Also, Clause 2, Article 79 of the LEP stipulates that in cases where households and individuals fail to classify or classify not as prescribed in Points a and b, Clause 1, Article 75 of the LEP, they must pay charges for collection, transport and treatment services as other types of domestic solid waste. With these provisions in the LEP mentioned above, households, individuals can choose between classifying domestic solid waste according to regulations or paying charges for collection, transport and treatment of domestic solid waste in case of non-separation at source or improper separation at source. At the same time, the LEP has shown the spirit of encouraging, not requiring, the implementation of separation at source of domestic solid waste through assigning responsibility to the Vietnamese Fatherland Front Committee and socio-political organizations at different levels to mobilize communities, households, and individuals to classify domestic solid waste. Besides, the implementation of the separation at source of domestic solid waste depends on natural, socio-economic conditions, infrastructure for collection, transport and treatment, specific treatment technology applied in each locality in practice.

International experience shows that there are no general regulations applicable across the entire country, but each state or each region has different separation at source methods to ensure the effectiveness of waste recycling and treatment. Therefore, the MONRE has developed the Technical Guidance on separation at source of domestic solid waste in the form of an official dispatch as a basis for the Provincial People's Committee to study and apply in the process of developing and promulgating detail regulations to ensure feasibility in each locality.

SEPARATION AT SOURCE OF WASTE TO OPTIMIZE WASTE RESOURCES

Separation at source of domestic solid waste aims to separate waste worth recycling at source, contributing to creating a source of raw materials for recycling activities and reducing the volume of domestic solid waste landfilled. Accordingly, the Technical Guidance on separation at source of domestic solid waste provides maximum identification of the types of domestic solid waste generated from households and individuals, classifying waste into 3 main waste groups in accordance with Clause 1, Article 75 of the LEP such as: (1) Reusable and recyclable solid waste is divided into 8 subgroups including waste paper; waste plastic; waste metal; waste glass; fabric, leather goods; wooden goods; rubber; discarded electrical and electronic equipment. (2) Food waste; (3) Other domestic solid waste is divided into 3 subgroups including hazardous waste; bulky waste; other waste.

For reusable and recyclable solid waste such as waste paper, waste plastic, waste metal, waste glass... it is necessary to remove water and solution contained inside, food, original container; compact, flatten, reduce size and volume; collect and stack sharp objects to avoid injury during separation at source, collection and treatment. For waste that is fabric, leather, and wood, clean objects and intact objects should be reused; compact, reduce size and volume of damaged items for recycling. For discarded electrical and electronic equipment such as cameras and video recorders; mobile phones and landline phones; desktop computers and monitors; refrigerators, freezers, air conditioners... need to keep their shape and do not disassemble.

For food waste such as leftovers; expired food; vegetables, tubers, berries, fruits and waste parts after preparing and cooking food, etc.; discarded products from livestock and poultry meat; seafood, those must be guaranteed to be stored in sealed containers, bags, packaging, etc., without leaks, preventing odours from spreading.

For other domestic solid waste that is divided into 3 subgroups:

Hazardous waste subgroup is packaging containing pesticides, waste acids, waste solvents, waste alkalis... from daily activities; paints, inks, adhesives (types with hazardous ingredients in production raw materials); gloves, rags stained with oil and chemicals; contaminated needles, masks, and bandages from patients must be stored in containers, bags, packaging, etc for safety and to avoid dispersing hazardous waste into the environment; collect and stack sharp objects (such as needles) to avoid injury during separation at source, collection and treatment. For waste as waste fluorescent light bulbs; waste activated glass; thermometer containing waste mercury, do not break them. In case of breakage, store them safely to avoid injury and prevent the spread of mercury during separation at source, collection and treatment. For waste batteries and accumulators, must keep their shape and do not disassemble.

▲ *Separation at source of domestic solid waste in Da Nang*

Bulky waste subgroup such as old and broken cabinets, tables and chairs, sofas, beds, mattresses; iron cabinets, door frames, doors... they need to be compacted, reduced in size and volume. In case of dismantling, the waste is then classified into corresponding waste groups.

Other remaining waste subgroup is nut shells, egg shells, coconut fiber, straw, rice husks... from daily activities; sedge mats; bamboo mats; rattan, bamboo pillows...; cattle and poultry hair...; coffee grounds, tea (tea bags), sugarcane bagasse, sugarcane residue, corn cob...; gardening waste from households such as leaves, roots, small branches, grass, flowers... they need to be compacted, reduced in size and volume. For pet feces; car casses of pet animals that die not due to disease... they need to be stored in a sealed, leak-proof container to prevent the spread of odours. For waste as used diapers, bandages, toilet paper, and tissue paper; all kinds of foam boxes; single-use plastic products; gum residue, cigarette filters...; balloons, tape, earring picks, toothpicks; medicine shells... they need to be compacted, reduced in size and volume, ensuring to avoid spillage.

To implement regulations on separation at source of domestic solid waste, the MONRE is responsible for stipulating technical requirements on environmental protection for aggregation points and transfer stations of domestic solid waste in Clause 2, Article 76; stipulating technical requirements on environmental protection for vehicles transporting domestic solid waste; promulgating criteria on domestic solid waste treatment technology; developing guidance on pricing methods for domestic solid waste treatment services; stipulating economic and technical norms on collection, transport and treatment of domestic solid waste; guiding the technical separation at source of domestic solid waste; guiding the implementation of provisions (Clause 1 and 5, Article 79); guiding for closing landfill sites for domestic solid waste (Clause 4, Article 80).

People's Committee of provinces and centrally run cities are responsible for deciding on the specific separation at source of other domestic solid waste according to the Guidance of the MONRE (Clause 2, Article 75); arranging premises for aggregation points and transfer stations for domestic solid waste to meet environmental protection requirements according to regulations of the MONRE (Clause 2, Article 76); selecting establishments to collect and transport domestic solid waste (Clause 1, Article 77); selecting establishments to treat domestic solid waste (Clause 2, Article 78); planning and allocating land fund for domestic solid waste treatment area, implementing timely land allocation to deploy construction and operation of domestic solid waste treatment area in the local area; allocating funds for investment in construction and operation of collection, storage, transfer, transport and treatment systems of domestic solid waste, systems of public works, measures and equipment serving the management of domestic solid waste in the area (Clause 6, Article 78); stipulating in detail the management of domestic solid waste of households and individuals in the area; stipulating specific prices for services of collection, transport and treatment of domestic solid waste; stipulating the specific form and level of funding that households and individuals must pay for the collection, transport and treatment of domestic solid waste based on the mass or volume of classified waste (Clause 6, Article 79).

People's Committee of provinces and centrally run cities shall study and apply the Technical Guidance on separation at source of domestic solid waste to develop plans and implement separation at source activities of domestic solid waste generated from households, individuals in the area, ensuring compliance with provisions of the LEP and guiding documents for implementation which note the separation at source of domestic solid waste to promote increased reuse and recycling of waste and discarded products, maximize the value, and extend the life cycle of products and materials; encourage agencies, organizations, communities, households and individuals to participate in recycling and treatment programs for waste produced and imported by organizations and individuals in accordance with provisions of the LEP and other documents guiding the implementation; minimize the amount of waste that must be treated. The separation at source of domestic solid waste needs to be consistent with the existing environmental protection technical infrastructure and waste treatment technology, natural, economic and social conditions; consistent with waste management content in provincial master plans and national environmental protection master plans, local financial resources.

In addition, People's Committee of provinces and centrally run cities organize propaganda and dissemination for agencies, organizations, communities, households, and individuals to classify domestic solid waste from households and individuals; implement the separation at source of domestic solid waste no later than 31st December 2024 ▪

NGUYỄN HẰNG

Global Waste Management Outlook 2024: Turning rubbish into a resource

Titled "Beyond an age of waste: Turning rubbish into a resource," the UNEP Global Waste Management Outlook (GWMO 2024) provides the most substantial update on global waste generation and the cost of waste and its management since 2018. The analysis uses life cycle assessments to explore what the world could gain or lose through continuing business-as-usual, adopting halfway measures, or committing fully to zero waste and circular economy societies. According to a new UN Environment Programme (UNEP) report, with municipal waste set to rise by two thirds and its costs to almost double within a generation, only a drastic reduction in waste generation will secure a liveable and affordable future.

MUNICIPAL SOLID WASTE GENERATION, GROWTH AND MANAGEMENT

This report focuses on Municipal Solid Waste (MSW), which is the waste generated by householders, retailers and other small businesses, public service providers and other similar sources. Managing MSW is generally a local service and is commonly the responsibility of local government. MSW is only a part of the story, since enormous amounts of non-municipal waste are generated each year.

MSW typically includes food waste; packaging; household items including broken furniture and electronic goods; clothes and shoes; and personal hygiene products. Its composition varies from place to place and may be affected by the time of year, weather conditions and economic recessions or other major events and trends.

The management of MSW poses unique challenges due to its sheer volume, continual growth, diverse composition, ubiquity in human settlements, variability and influence by cultural change, and the intricate web of social, economic and environmental impacts that arise from its management.

MSW management being delivered by municipal governments, formal and informal private actors, and civil society. Questions of global social and environmental justice also arise in discussions of municipal waste growth and its management, as illustrated by the many links with the Sustainable Development Goals (SDGs) (Table 1) (United Nations Environment Programme [UNEP] 2023).

Table 1: Waste management and its links to the Sustainable Development Goals


Table 1: Waste management and its links to the Sustainable Development Goals

SUSTAINABLE DEVELOPMENT GOALS

Goal 1. No poverty: Waste workers in informal economies who have no health or social protections are vulnerable to exploitation and are paid only the material value of the materials they collect. Inclusive municipal waste management policies are most effective for addressing both poverty and pollution.

Goal 2. Zero hunger: While global hunger is increasing, one-third of all the food grown in the world is wasted. Hunger can be reduced by preventing food waste and redistributing excess food. Converting unavoidable food waste into compost can replenish depleted agricultural soils.

Goal 3. Good health and well-being: Communities without adequate municipal waste management services resort to dumping and open burning, both of which have significant negative health consequences, particularly for women and children.

Goal 4. Quality education: Waste management courses in tertiary and higher education are uncommon, resulting in a lack of professional technical capacity and a shortage of workers with appropriate skills and knowledge.

Goal 5. Gender equality: People's experience with waste and its management is gender-differentiated: e.g. household purchasing and domestic waste-generating activities, and levels of influence over community decision-making regarding waste collection services.

Goal 6. Clean water and sanitation: Pollutants leaching from dumpsites can contaminate freshwater sources and associated food chains. Meanwhile, combining municipal solid waste and container-based sanitation services can achieve economies of scale that make both services more attractive to investors.

Goal 7. Affordable and clean energy: Unavoidable food waste can be used to make biogas, a clean-burning renewable fuel that could be used to tackle energy poverty, including in off-grid communities.

Goal 8. Decent work and economic growth: The waste management and recycling sector is uniquely positioned to improve global resource efficiency, decouple economic growth from environmental degradation, and provide safe and decent work opportunities for all.

Goal 9. Industry, innovation and infrastructure: Decentralised waste management systems can attract private sector investment, encouraging innovation, entrepreneurship, domestic technology development, greater resource efficiency and increased employment opportunities, and reduce financial risks for governments and municipalities.

Goal 10. Reduced inequalities: Intragenerational and intergenerational inequalities must be addressed through developing waste and resource management systems; attention is required from all stakeholders because the transition to a more circular economy will not occur by default.

Goal 11. Sustainable cities and communities: Solid waste management is a basic utility service without which air quality and living conditions become degraded, leading to poor health and social discontent. To make cities and communities inclusive, safe, resilient and sustainable, universal access to municipal waste management services is essential.

Goal 12. Responsible consumption and production: Production and consumption patterns directly impact municipal waste generation. To reduce waste and prevent pollution, efforts are needed by companies, governments and citizens.

Goal 13. Climate action: Poorly managed waste generates a wide range of emissions that contribute to climate change, most significantly methane from landfills and dumpsites, and black carbon and a range of other emissions from the widespread practice of the open burning of waste.

Goal 14. Life below water: Understanding why and how land-based waste reaches the sea, and introducing mitigation measures, is essential. Urgent action is particularly required in the case of Small Island Developing States, which face a complex set of waste management challenges.

Goal 15. Life on land: The terrestrial environment continues to be the primary sink for waste, while rural communities face complex waste management challenges that if left unmanaged can significantly impact ecosystems and dependent livelihoods.

Goal 16. Peace, justice and strong institutions: The increasingly global nature of waste management calls for heightened international cooperation to build national capacity for the safe management of hazardous waste and to prevent its illegal trafficking.

Goal 17. Partnerships for the Sustainable Development Goals: Current investments in waste management are insufficient. Far higher investments will be needed in the future to cope with increasing waste generation and the accumulation of legacy waste. The return on investment for waste management needs to be realised to catalyse increased finance.

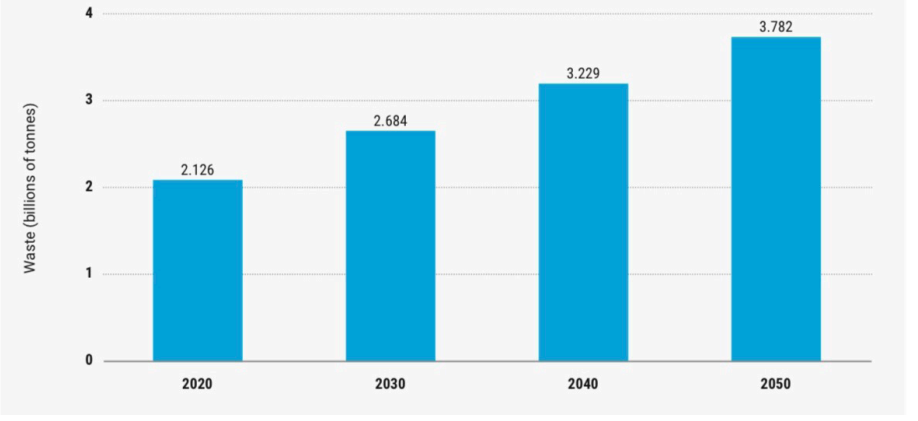
Source: United Nations Environment Programme 2023

Source: The UNEP Global Waste Management Outlook

According to the report, municipal solid waste generation is predicted to grow from 2.3 billion tonnes in 2023 to 3.8 billion tonnes by 2050. In 2020, the global direct cost of waste management was an estimated USD 252 billion. However, when factoring in the hidden costs of pollution, poor health and climate change from poor waste disposal practices, the cost rises to USD 361 billion. Without urgent action on waste management, by 2050 this global annual cost could almost double to a staggering USD 640.3 billion (Figure 1).

Waste generation is intrinsically tied to GDP, and many fast-growing economies are struggling under the burden of rapid waste growth. By identifying actionable steps to a more resourceful future and emphasising the pivotal role of decision-makers in the public and private sectors to move towards zero waste, this Global Waste Management Outlook can support governments seeking to prevent missed opportunities to create more sustainable societies and to secure a liveable planet for future generations.

Figure 1 : **Projections of global municipal solid waste generation per year in 2030, 2040 and 2050 if urgent action is not taken.**



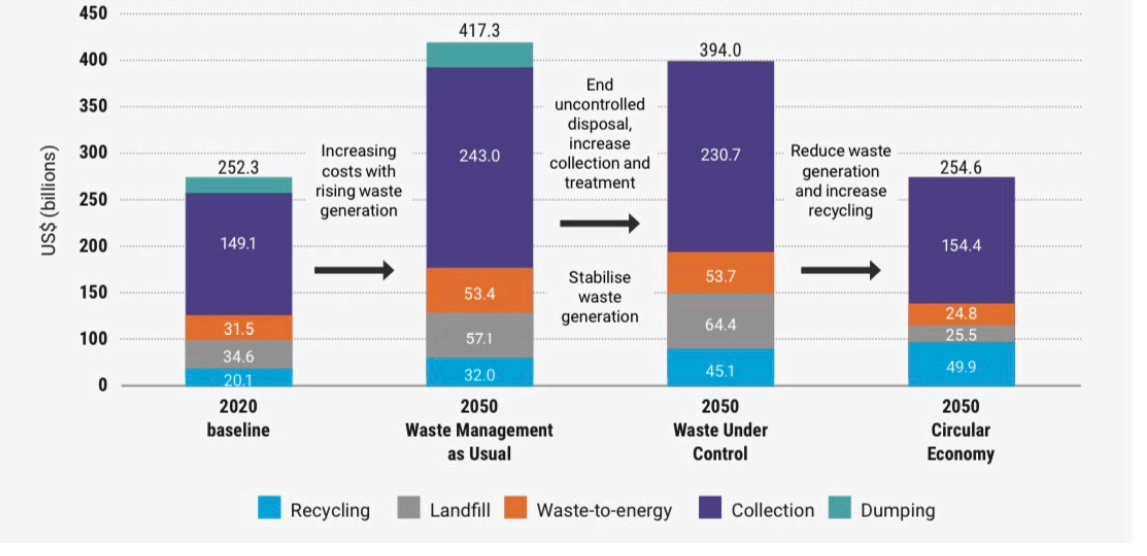
▲ *Figure 1: Projections of global municipal solid waste generation per year in 2030, 2040 and 2050 if action is not taken*
Source: GWMO 2024

Notwithstanding the need for upstream measures to reduce waste and, ideally, decouple waste generation from economic growth, this report looks at how MSW is currently managed: Access to waste collection services varies significantly within and between regions. Reuse and recycling reduce demand for energy-intensive and environmentally damaging raw material extraction enable waste to be valued as a resource, and prevent pollution from waste leaking into the environment. Recycling is not the ultimate goal of waste management: it is always better to reduce waste by preventing it in the first place, or reuse materials that would otherwise become waste, than to produce waste and then recycle it. Waste-to-energy represents linear resource use since materials that are combusted can never be recovered and used again. A sanitary landfill is an engineered facility for the disposal of solid waste on land in a controlled manner. Dumpsites are prone to fires, which can smoulder continuously beneath the surface for months and can be very difficult and dangerous to extinguish.

Unsustainable consumption and production patterns result in increasing quantities of waste to manage, which in turn increase the direct costs to society. The analysis carried out for this report found that in 2020 MSW management globally cost US$252.3 billion. Improving waste management worldwide will require significant investments, by far the most affordable solution is to drastically reduce waste and value secondary materials as a resource (Figure 2).

The GWMO 2024 is a guide and call for action to catalyse collective efforts to support bold and transformative solutions, revert the adverse impacts of current waste management practices, and provide clear benefits to every individual living on this planet. These actions are instrumental to accelerating the achievement of the 2030 Agenda.

Figure 2 : **Global direct costs of municipal solid waste management in 2050 under the three scenarios (US$ 2020).**



▲ *Global direct costs of municipal solid waste management in 2050 under the three scenarios*

Source: GWMO 2024

The findings of this report demonstrate that the world urgently needs to shift to a zero waste approach, while improving waste management to prevent significant pollution, greenhouse gas emissions and negative impacts to human health. Pollution from waste knows no borders, so it is in everyone's interests to commit to waste prevention and invest in waste management where it is lacking. The solutions are available and ready to be scaled up. What is needed now is strong leadership to set the direction and pace required, and to ensure no one is left behind (Table 2).

Jointly published with the International Solid Waste Association (ISWA), the report provides an update on global waste generation and the cost of waste and its management since 2018. The analysis uses life cycle assessments to explore what the world could gain or lose through continuing business-as-usual, adopting halfway measures, or committing fully to zero waste and circular economy societies. The report also evaluates three potential scenarios of municipal waste generation and management, examining their impacts on society, the environment, and the global economy. Furthermore, it presents potential strategies for waste reduction and enhanced management, following the waste hierarchy, to treat all waste materials as valuable resources. To assess the potential impacts of MSW management to 2050, three scenarios were developed.

Table 2: **Just transition elements as applied to waste reduction and waste management (after Impact Investing Institute 2023)**

Advance climate and environmental action	Improve socioeconomic distribution and equity	Increase community voice
• Focus on upstream waste prevention and reducing greenhouse gas emissions from linear resource use. • Protect and restore natural capital, including biodiversity. • Support adaptation and resilience to climate change.	• Efforts to reduce and manage waste must be complemented by activities that support the needs of people. • Investments should not entrench or exacerbate existing burdens for people already disproportionately affected by poor environmental quality or lack of access to services and to safe, dignified livelihoods.	• Improve social dialogue and agency, from local engagement to participation and decision-making. • Any financing transaction that claims to contribute to a just transition must involve stakeholders and ensure that their voices are heard. These stakeholders include workers, communities, consumers and indigenous and marginalised communities.

Source: GWMO 2024

BARRIERS TO CHANGE

This report explores the reasons why, despite awareness of the global waste crisis, progress towards waste prevention and improved waste management is not occurring rapidly enough. For waste mangement systems to be effective and efficient, behavioural change may be required in hundreds of thousands of households. Insufficient attention to waste reduction is largely responsible for rapid waste growth globally. Many countries are unable to provide waste management services for all citizens.

Political leaders need to recognise the urgency of the waste crisis and its impacts on society. While municipalities are typically responsible for waste management, no single stakeholder has responsibility for waste reduction despite its clear public benefits and priority position on the waste hierarchy. Consequently, zero waste and circular economy business models that could help to decouple economic growth from waste generation have too often been considered secondary to waste management. It's time to clean up our world, and make progress towards circular, zero-waste economies - for people and planet alike.

Waste generation can be decoupled from economic growth. The city of Kitakyushu in Japan stands out as an example of achieving waste reduction, with only 0,42kg of municipal solid waste generated per person per day. As an industrial city with significant pollution, Kitakyushu sought to apply an environmentally sound approach rather than a disposal-focused one. The main drivers of its efficient waste management system cover all steps from start to end points: sorting of waste at the source, composting widely at the household level, recycling and heavy engagement of citizens. These measures are complemented by financial incentives to reduce waste through volume-based waste user fees rather than flat fees per household. Over time, Kitakyushu has also created an eco-town to increase environmental awareness and recover materials from many types of waste, including cars and appliances.

In many countries, most urban waste collection and transportation are carried out by the informal recycling value chain, helping cities to save money. However, many policymaking and infrastructure development projects fail to harness this local expertise. Without hearing the voices of this existing workforce, potential system design improvements may be missed while the negative consequences of policies and infrastructure may be overlooked (UNDP 2022).

Returnable plastic packaging can achieve meaningful environmental benefits compared to single-use plastic packaging, with the potential to reduce emissions and water use by 35% - 70%.

The aim of this report is to make clear the shared direction in which countries need to travel so as to become more resource efficient, and to have better public health, and to offer actionable pathways to deliver change at pace. Countries with the least formal waste management systems have perhaps the most to gain from digitalisation. All countries can take steps towards ensuring goods and services are provided in such a way as to avoid unnecessary waste.

RECOMMENDATIONS

We need to act now in order to avoid the worst scenario. The report provides guidance and suggested actions for multinational development banks, national governments, municipalities, producers and retailers, the waste management sector as well as citizens. The following recommendations therefore focus on the shape of that leadership, including how governments and industry can engage to create the enabling conditions for a circular economy, and ultimately zero-waste societies.

Multinational development banks, donors and philanthropic organisations: Recognise the importance of integrating improved waste management zero-waste waste and circular economy strategies; identify proven solutions and support their replication and scaling up in different cities, countries and regions; share lessons learned openly so that repetition of failures can be avoided and successes replicated; take into account the track record of a particular solution when assessing proposals so that the most effective approaches are those that receive the greatest support; require governments, municipalities and other partners to collect gender-disaggregated data on experiences with and impacts of waste, to better inform policies and other interventions

National governments: Legislate for the waste hierarchy; pursue all opportunities to encourage waste reduction and circular economy initiatives at a national and sub-national level, for example by introducing incentives for zero waste service delivery models, and modulated fees that promote waste reduction in producer responsibility schemes; integrate policies for waste management and circular economies to prioritise waste reduction and maximise the value of secondary resources within society; use national legislation to protect the rights of the informal waste sector and ensure their support and involvement in developing waste management services; legislate for equal access to a waste management service; provide guidance for municipalities in how to provide waste services economically and effciently, including by encouraging citizens to reduce waste, reuse and recycle within the home; provide guidance for municipalities in waste management system design, ensuring inclusion and representation from women and the informal sector, and that systems are tailored for the needs of the local community; build national waste management and circular economy expertise; pursue opportunities to share knowledge and learn from other countries with similar contexts.

Municipalities: Cooperate between municipalities to share and replicate good practice and achieve economies of scale in service delivery; recognise the specifc experience and expertise of both women and the informal sector and to advance waste reduction and involve them in waste management service design; lead by example in the community by identifying opportunities to drive resource effciency; raise awareness through positive and targeted messaging; and make it easy for residents and local businesses to reduce waste and participate in waste segregation programmes; encourage residents to reduce waste and where possible manage waste in the home; involve the local community and provide meaningful opportunity for feedback on waste reduction and waste management strategies; ensure systems are co-designed with service users to promote ownership and accountability and to embed behaviour change; be patient and stay motivated - behaviour change around waste reduction and waste segregation takes time and consistency; keep going one step at a time.

Producers and retailers: Recognise the vital role and responsibility of the private sector in waste prevention; take responsibility for waste generation and respond to society's demands and needs to reduce the resource-use footprint of commercial activities; pursue business models that achieve fnancial savings through resource effciency, such as refll, deposit return and design-for-recycling; support governments with efforts to regulate waste generation, recognising that regulation creates a level playing feld and gives certainty; favour regulation over voluntary targets which only add to uncertainty; avoid greenwashing.

Waste management sector: At all times seek opportunities to move waste management practices up the waste hierarchy; use expertise about material resources to support waste reduction, resource effciency and circular economy models; help governments and municipalities to design systems that are locally appropriate and can be adapted to meet the changing needs of society.

Citizens: Pursue conscious consumerism, buying only what is needed and avoiding goods that are over-packaged, unnecessarily single-use or have a short lifespan; use refll and deposit return schemes where they exist; where possible, reuse and recycle at home to reduce waste and its burden on municipalities and the environment, for example by home composting; segregate unavoidable waste into three streams for its economical and sustainable management: food and garden waste, dry and clean recyclables, and residual waste; use consumer power to infuence business practices; support local businesses that offer goods and services in a way that promotes zero waste and a circular economy

The Global Waste Management Outlook 2024 echoes the first GWMO's call to action to scale up efforts to prevent waste generation; to extend adequate safe and affordable MSW management to everyone worldwide; and to ensure that all unavoidable waste is managed safely ▪

NHÂM HIỀN

Source: The UNEP Global Waste

Green transition in tourism for sustainable development

PATRICK HAVERMAN
UNDP Deputy Resident Representative

Tourism has emerged as a vital sector in Vietnam's economy, projected to contribute over 6.4 percent to the GDP by 2024, thanks greatly to Vietnam's natural beauty and cultural heritage that attract millions of visitors annually. As we confront challenges like biodiversity loss and climate change, a shift towards sustainability is imperative. Green transition in tourism not only benefits the environment and supports biodiversity conservation but also uplifts communities that are reliant on tourism and fosters economic growth.

Green transition in tourism for Vietnam should embrace the following endeavors of i) green planning; ii) effective destination management; iii) plastic-free and low-carbon tourism; and iv) sustainable nature-based tourism.

GREEN PLANNING

As we kickstart our journey towards a greener future, it's crucial to begin our conversation with "green" planning. In other words, national planning needs to lead the way towards green tourism development, in particular, in low-impact tourism infrastructure development that ensures efficient solid waste and wastewater management, among others. This is especially important in places like marine protected areas and national parks, where sensitivity to environmental impact is paramount.

EFFECTIVE AND INCLUSIVE DESTINATION MANAGEMENT

In Viet Nam, there's a significant opportunity for enhancing tourism destination management. In our view, destination management is a process that should be led by the local authorities, in very close collaboration with the private sector and communities, with their voice and views heard and reflected in tourism management measures.

By implementing effective destination management practices, we can introduce

▲ *Green transition in tourism*

important regulations like bans on plastics and address other tourism-related issues in a comprehensive and inclusive manner, ultimately improving the overall tourist experience. Moreover, this approach allows us to identify and leverage the unique natural and cultural assets of each locality, fostering the development of distinctive tourism offerings.

PLASTIC-FREE AND LOW-CARBON TOURISM

In our commitment to a greener future, we need to embark on a journey towards a plastic-free environment and low carbon tourism. Various regions in Vietnam are already "greening" tourism. For instance, Hoi An and Co To islands are actively reducing single-use plastics, showcasing a commitment to environmental stewardship.

Through initiatives like "Reducing plastic waste in tourism in Viet Nam" project that is implemented by the Viet Nam Tourism Association (VITA) and UNDP, we have undertaken the important task of disincentivizing and monitoring plastic waste produced from tourism.

The project focuses on empowering tourism enterprises to go plastic-free, with the development of clear criteria for recognition of such entities, the introduction of a mobile app for waste management and monitoring, and the implementation of a robust action plan to curtail plastic waste in the sector.

In addition, green transport holds great potential for advancing green tourism. Encouraging green transport in tourism will provide an additional flexible and eco-friendly means of transportation for tourists visiting the destinations. This initiative will contribute to improving the local air quality and aligning the tourism sector with the government's commitment to achieving net zero emissions.

SUSTAINABLE NATURE-BASED TOURISM

Viet Nam embraces an extensive cluster of terrestrial and marine protected areas which are key resources for the development of nature-based tourism where indigenous cultures, biodiversity conservation, and rural economic growth meet.

However, implementing NBT in a sustainable manner will require meticulous planning and thoughtful consideration. This involves assessing the potential impacts on the fragile ecosystems within these protected areas, ensuring that any tourism activities align with conservation goals, and actively involving local communities in decision-making processes to promote both environmental preservation and socio-economic development.

Through the "Promoting wildlife conservation and responsible nature-based tourism in Viet Nam" project, UNDP and Vietnamese partners (MONRE, MOCST, Quang Binh and Ninh Thuan provinces) are actively working to bring this vision to life. Our efforts have focused on leveraging private investment via public-private partnerships, evaluating tourism sites' readiness to welcome visitors, fostering community involvement, establishing fair benefit-sharing arrangements, and promoting a shift in societal attitudes towards sustainable nature-based tourism.

UNDP stands ready to support the Ministry of Culture, Sports & Tourism, Vietnam Tourism Association, and other stakeholders in transforming Vietnam into a competitive and responsible tourism destination. A green transition in tourism not only poses as one of the major driving forces for economic growth but also safeguards Viet Nam's precious natural resources for generations to come ▪

The global ocean - Earth's seas, including the Arctic, Atlantic, Indian, Pacific, and southern oceans - provide more than half of the oxygen we breathe, and providing food and livelihoods for billions of people worldwide. It is also home to many magical wildlife species, from tiny plankton to the largest creature that has ever existed - the blue whale. The extraordinary diversity of ocean life and the services they provide to humans are of great value.

THE IMPORTANCE AND CURRENT STATUS OF THE OCEANS

The ocean accounts for more than 70% of the Earth's surface, playing an important role in the socio-economic development of humanity. It is estimated that the goods and services the ocean provides – from fishing to tourism and coastal protection – are worth at least $2.5 trillion each year; two-thirds of global marine product depends on a healthy ocean; 30% of human CO_2 emissions are absorbed by the ocean; 500 million people depend on coastal resources for food; 90% of the world's seafood comes from small-scale fisheries.

Yet the ocean has undergone significant changes over the past century. The world has lost half of its coral reefs and mangrove forests. And humans have pushed many important fish stocks to the point of decline, threatening people's livelihoods and food security, while harming other species

High sea treaty for oceans conservation

ĐỖ TUẤN ĐẠT
Center for Action and Alliance for Sustainable Development

including seabirds, turtles and dolphins. Furthermore, migratory marine species are freely distributed between national waters and the high seas, of which two-thirds of the world's oceans are beyond the control of individual countries, but currently there is only about 1% protected marine areas, leaving marine species and ecosystems exposed to the impacts of unsustainable industrial fishing practices.

In addition to the potential degradation of an ocean ecosystem, the inequality of the fishing industry is a matter of concern. Fishing, shipping, tourism and ocean protection are currently controlled by states and about 20 international organizations. However, their regulations only apply to distances of 200 nautical miles (370 km) from the coast, i.e. exclusive economic zones (EEZ). Outside these areas are international waters. Although international waters cover more than half of the Earth's surface and 61% of all oceans, only 1% of this area is protected. There is illegal fishing, overfishing and other forms of damage to ecosystems.

In West Africa, fish stocks are being seriously depleted due to large fishing vessels from Europe operating offshore. This is causing food insecurity across the region and harming the livelihoods of fishermen who provide for their families through trading. The problem is most acute in coastal areas - home to some of the most valuable natural resources but also more densely populated than anywhere else on Earth. Coastal communities are increasingly vulnerable to storm damage and food shortages due to the loss of coral reefs, mangroves and seagrass beds.

Pollution from plastic to oil spills and agricultural chemicals also harms nature, contaminating the food chain. About 80% of global wastewater is currently sent into the oceans without filtration. In the world's poorest countries, this figure is nearly 95%. This wastewater pollutes, contaminates, and destroys oceans and coastal areas. Therefore, building sustainable wastewater treatment systems, especially in developing countries, will protect ocean ecosystems and contribute to better drinking water supplies in many places.

Climate change is making the ocean hotter and more acidic, which will spell disaster if left unchecked. More than half of the oxygen in the atmosphere is produced by organisms in the ocean. At the same time, the oceans store 50 times more carbon dioxide (CO_2) than what is currently in our atmosphere. The warmer the ocean gets, the less CO_2 it can store. Thus, the oceans are less able to protect the planet from extreme weather events. If temperatures continue to rise at the current rate, scientists say many shellfish species such as clams and snails will not be able to survive. That is due to ocean acidification, if the CO_2 content in sea water increases, the pH in the water will change. Increasing acidity interferes with the production of crustaceans' chalky shells. This unbalances the entire biosphere and can therefore threaten marine economies.

Rising temperatures in the atmosphere from burning coal, oil and gas also change ocean currents as the water gets warmer. This means death for many marine creatures, such as coral reefs. These ocean forests live in symbiosis with algae. Water warming can lead to the death of seaweed, which means more stress for corals, causing many species to lose their color, a phenomenon known as coral bleaching.

THE HIGH SEA TREATY ON OCEAN CONSERVATION

On December 19th, 2022, in Montreal, Canada, the 15th Conference of the Parties to the Convention on Biological Diversity (COP15 CBD) approved the Kunming-Montreal Global Biodiversity Framework with the participation of 190 countries aim to orient the conservation of nature and biodiversity globally to 2030 and a vision to 2050. Accordingly, countries around the world commit "To take urgent action to halt and reverse biodiversity loss to put nature on a path to recovery for the benefit of people and planet". The framework includes four overarching goals supported by 23 targets, but the one that has received the most attention is the commitment to protect and conserve at least 30% of the ocean and ensure that 30% of degraded will be restored by 2030. This is a global task.

The Agreement on the Conservation and Sustainable Use of Marine Biodiversity in Areas Beyond National Jurisdiction (BBNJ), also known as the Agreement on the High Seas, is an important step towards implementing the Kunming - Montreal of the United Nations. The Agreement was officially adopted at the 5th session of the United Nations Intergovernmental Conference on June 19th, 2023 in New York (USA)... The birth of the High Seas Treaty is considered a historic victory following the 1982 United Nations Convention on the Law of the Sea (UNCLOS) in building and enforcing legal order at sea.

UNCLOS is a document considered the Constitution of the seas and oceans, which sets out regulations on freedom of navigation, freedom of fishing and freedom of scientific research at sea in areas outside the exclusive economic zone.... However, UNCLOS does not have any provisions

▲ *Ocean is also home to many magical wildlife species*

specifically addressing access, use and sharing of benefits from marine biodiversity resources located outside areas under national jurisdiction, nor there is no mechanism to coordinate and control activities at sea to protect genetic resources from decline and depletion. Meanwhile, biodiversity in waters beyond national jurisdiction is currently facing many risks. Sea areas, which do not belong to any country's jurisdiction, have special species that only live in deep waters or offshore, bringing great values in terms of biodiversity and economically, is under serious threat.

Competition to extract value from areas beyond national jurisdiction is increasing in pursuit of the enormous economic benefits that marine genetic resources bring. However, currently only developed countries and private companies possessing advanced marine technology and biotechnology, with abundant financial resources, are capable of collecting marine genetic resources and developing profitable applications.

The High Seas Treaty provided the legal framework to conserve marine life and limit harmful activities in areas beyond national jurisdiction. The Ocean Agreement sets out regulations on marine conservation zoning measures, aiming to balance conservation and sustainable use of protected areas. In addition, regulations on environmental impact assessment are also expected to contribute to balancing the need for scientific research and the goal of preventing harm caused by activities on the high seas to marine biodiversity. The treaty has created a framework and method for member countries to share benefits with each other, helping countries, especially developing countries, to receive more equitable benefits from marine genetic resources. In addition to economic benefits, developing countries will also have more opportunities to participate in marine scientific research, capacity building and technology transfer...

As a coastal country, Vietnam participated in the document negotiation process from the beginning. On September 20th, 2023 in New York, within the framework of the High-Level Week of the 78th United Nations General Assembly, Vietnam signed the Agreement on the High Seas. Signing The Agreement has many important meanings for Vietnam, demonstrating that Vietnam is an active and responsible member of the international community, joining hands with countries around the world to solve global problems and contribute into peace, prosperity and sustainable development.

The agreement opens up opportunities for Vietnam and other developing countries to participate in scientific research, transfer marine technology, and benefit economically from the fact that other countries have greater advantages in financial science and technology potential, to exploit genetic resources in the high seas and share benefits. This is especially meaningful in the context of Vietnam's marine economic development strategy to 2030, vision to 2045, which identifies "Development of science, technology and training of high-quality marine human resources"... as one of the key breakthroughs and solutions to realize the goal of "Vietnam becoming a strong maritime nation with sustainable development, prosperity, security and safety; The marine economy makes an important contribution to the country's economy, contributing to building our country into a modern industrial country with a socialist orientation."

The Agreement creates and encourages international cooperation mechanisms and regional marine cooperation with the goal of preserving and sharing benefits from marine genetic resources. These are opportunities for Vietnam to promote cooperation, strengthen the overlap of interests, and contribute to protecting the Fatherland.

The High Seas Treaty marks an important turning point in protecting ecosystems in vast international waters. This is considered a historic agreement to help save ocean biodiversity and promote sustainable development. The Treaty will contribute to the conservation and sustainable use of marine resources, while protecting the rights and interests of all countries involved ■

The need to protect migratory species worldwide

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Billions of animals are regularly on the move anually. These species migrate on land, in water and in the sky. Migratory species include some of the most iconic species on the planet such as sea turtles, whales and sharks in our oceans, elephants, wild cats, and herds of hooved species that cross plains and deserts, raptors, waterbirds and songbirds that cross through the skies, and even insects such as the monarch butterfly. They travel frequently, sometimes thousands of miles, to reach places where they breed or feed, but they also face enormous challenges and threats along the way. When species cross national borders, their survival depends on the efforts of all the countries in which they are found.

Therefore, the Convention on the Conservation of Migratory Species of Wild Animals (CMS) was adopted in June 1979 to conserve and effectively manage migratory species and their habitats, while recognizing that the conservation of migratory species requires the cooperation of countries across national boundaries, in all places where those species spend any part of their life cycle. The Convention has grown in scope and scale over the past four decades since its adoption in June 1979. There are currently 133 CMS signatory countries. These countries have made commitments to take action to conserve migratory species and their habitats, as well as to address factors that impede their migration. In addition to the 133 CMS Parties, there are a further 28 countries that, although not Party to the Convention, are Party to one or more of the Agreements and/or are signatories to one or more of the Memoranda of Understanding (MOU) concluded under the umbrella of CMS. At the moment, there are 1,189 species listed in the two Annexes of the CMS Convention, of which there are 962 species of birds, 94 species of terrestrial mammals, 64 species of aquatic mammals, 58 species of fishes, 10 species of reptiles and 1 species of insect.

THE IMPORTANCE OF MIGRATORY SPECIES AND THEIR DECLINE

Migratory animals are essential components of the ecosystems that support all life on Earth. Globally, billions of individual animals embark on migratory journeys each year, connecting distant continents, countries and habitats through their migration routes. Migratory species are of ecological, economic and cultural importance. Within ecosystems, migratory species perform a variety of crucial functions, ranging from the large-scale transfer of nutrients between environments, to the positive impacts of grazing animals on grassland biodiversity [1,2]. People around the world are reliant on these species as sources of food, income and enjoyment. Along their migration routes, migratory species provide vital benefits for people, from pollination of crops to supporting sustainable livelihoods. Migratory species are also valuable indicators of overall environmental health as trends in the conservation status and behaviour of migratory species can provide an indication of the state of habitats along entire migration routes. However, declines in migratory species can lead to the loss of important functions and services. Conservation of migratory species can also support the continued resilience of ecosystems to changing environments, including mitigating the impacts of climate change.

According to a report by the Conservation Monitoring Center of the United Nations Environment Program (UNEP) published in mid-February 2024, migratory animals are currently facing risks all over the world. This is the first report on this issue, which focuses on the 1,189 species listed in the Appendices of the United Nations Convention on the Conservation of Migratory Species of Wild Animals (CMS). Overall, more than one in five species listed in the Appendices of CMS are threatened with extinction and a significant proportion (44%) have population trends that are decreasing. When looking at Appendices alone, 82% of species in Appendix I are threatened with extinction and 76% of species have a population trend of decline. Meanwhile, 18% of species in Appendix II are threatened globally, with nearly half (42%) showing a decreasing trend. The conservation status of fish species listed in CMS are of particular concern. Almost all (97%) of the fish species listed in CMS are threatened with extinction, and on average the number of fish monitored has plummeted over the past 50 years.

Additionally, levels of extinction risk are rising across CMS-listed species as a whole. Between 1988 and 2020, 70 CMS species showed a deterioration in conservation status, substantially more than the 14

species that showed an improvement in conservation status. Extinction risk is also escalating across the wider group of migratory species not listed in CMS, with 399 migratory species globally threatened and near threatened (mainly birds and fish). These species require further scrutiny from the CMS Parties and Scientific Panels and may benefit from being listed in the CMS Appendix. A total of 179 species listed in Appendix II were identified as "very high" (52 species, 5%) and "high" (127 species, 13%) priority for further conservation measures.

THREATS TO THE WORLD'S MIGRATORY SPECIES

Migratory species face a multitude of pressures, which are overwhelmingly caused by human activities. Due to their reliance on multiple geographically distinct areas, and their dependence on connectivity between these areas, migrants are more likely to be exposed to a diverse range of these threats, which can impact them at different stages of their migratory cycles. Here are the four main threats to the world's migratory species:

Overexploitation

Overexploitation of natural resources is the primary cause of biodiversity loss in the world's oceans and the second most important driver of global biodiversity loss on land. Migratory species across the world are harvested, taken and traded for a variety of reasons, including consumption as food (i.e. wild meat), transformation into products such as clothing and handicrafts, use as pets, belief-based use and sport hunting. According to the IUCN Red List, "overexploitation" is one of the main threats facing migratory species, and affects 70% of CMS-listed species. Nearly three quarters of all CMS-listed terrestrial mammals (70%) are targeted by hunters, largely to supply domestic demand for wild meat [4]. Hunting for food, sport and other purposes is also a pervasive threat to the many migratory birds that use the East Asian-Australasian flyway or migrate between Africa and Europe. While migratory birds often benefit from some legal protection, many are subject to pressure from illegal taking. Between 11 and 36 million birds are estimated to be illegally killed or taken annually in the Mediterranean region [2]. Early indications suggest that the scale of unsustainable and illegal take may be even higher in Southeast Asia [3].

Habitat loss, degradation and fragmentation

Habitat loss, degradation and fragmentation is among the main drivers of global biodiversity loss in terrestrial and freshwater ecosystems. The Serengeti-Mara ecosystem in the United Republic of Tanzania and Kenya is a prime example, experiencing significant pressure from the expansion of agriculture, settlements, roads and fences. This affects the quality and availability of habitat for some of the world's largest free-ranging populations of migratory ungulates, including blue wildebeest and plains zebra, which support populations of CMS-listed apex predators such as lion and African wild dog. Similarly, the modification and fragmentation of European rivers, through the construction of dams and other structures, has drastically reduced the suitability of these freshwater habitats for migrating European Eels [10].

Habitat destruction and degradation is also a significant driver of biodiversity loss in marine ecosystems, where the loss of habitats like seagrass meadows as a result of climate change, pollution, land reclamation and port expansion have triggered population declines in species like Dugongs that rely on seagrass as a food source [9,6]. As migratory species must be able to move between sites, they are particularly vulnerable to the loss of ecological connectivity that often results from habitat destruction and degradation.

There is therefore an urgent need to maintain, enhance and restore ecological connectivity to sustain the mobility of migratory populations between locations across their entire range and life cycle.

Climate changes

The impact of climate change is already being felt by many migratory species, and the role of climate change as a direct threat to biodiversity is expected to increase considerably in the coming decades [7]. In addition to increasing temperatures, climate change will result in changes in precipitation, extreme weather, sea level rise and ocean acidification, all of which have the potential to dramatically change habitats and their species composition [11]. While some migratory species may be able to adapt to climatic changes, many will not be able to do so, particularly where its cascading effects could see the degradation and loss of key habitats. Importantly, climate change may also act as an amplifier of other threats, such as habitat loss, pollution, and overexploitation [7].

Environmental pollution

Pollution is a key driver of recent biodiversity loss worldwide and includes contamination of the environment with artificial light, anthropogenic noise, plastic and chemicals [13,8]. According to the IUCN Red List, pollution is a threat to 276 CMS-listed species (43% of those with threats documented). Pollution can cause mortality directly, through toxic effects on individuals, or indirectly, by reducing food availability and degrading habitat

quality. It can also adversely affect reproductive and physiological performance and natural behaviours, including migratory behaviour. Given their reliance on multiple spatially separated habitats, migratory species may be more likely to encounter a diverse range of pollutants such as plastic pollution. Plastic pollution is not only widespread in marine environments but also affects terrestrial and freshwater species such as Indian elephants and Irrawaddy dolphins. Plastic affects wildlife primarily through entanglement (whereby animals become ensnared in items like bags or nets) or through the ingestion of small plastic materials [5].

RECOMMENDATIONS ON PRIORITY ACTIONS

The Convention on Migratory Species provides a global platform for international cooperation and the active participation of governments, communities and all other stakeholders in addressing the myriad of challenges that migratory species face. With the recently renewed global commitments established to address threats to biodiversity through the Kunming-Montreal Global Biodiversity Framework and with the adoption of the new strategy envisaged predicted at CMS COP14, collective efforts to deliver on these commitments and deliver on ambitions for migratory species are essential.

Protect, connect and restore habitats

Identify key sites for migratory species along their entire migratory pathways. Accordingly, it is necessary to identify important habitats and sites for migratory species such as Key Biodiversity Areas (KBAs) which identify nearly 10,000 important sites for CMS-listed species, but there are taxonomic and geographic gaps in the existing site network, particularly for migratory terrestrial mammals, aquatic mammals and fish.

Increase the coverage of KBAs and other critical habitats by protected and conserved areas. In line with global targets to expand the network of protected and conserved areas to over 30% by 2030, prioritizing those sites that are important for biodiversity is vital to ensure successful outcomes for nature. Currently more than half of the area of KBA sites identified as being important for CMS-listed species is not covered by protected or conserved areas, indicating there are clear gaps and more needs to be done.

Enhance the management effectiveness of protected and conserved areas. This includes ensuring sufficient resources are put into the management of protected and conserved areas to maximize the benefits for biodiversity. Given the scale of the threats to migratory species, improving the ecological condition of protected and conserved areas is essential to maintain environments for many species. To ensure the management needs of migratory species are taken into account, key priorities for migratory species should be integrated into management plans for these areas. More broadly, it is important that key conservation priorities for migratory species are also integrated into National Biodiversity Strategies and Action Plans (NBSAPs).

Establish, support and expand regular monitoring of important sites for migratory species, and of populations of migratory species at these sites, following standardized protocols. This is essential to identify the threats taking place and their impacts on species and ecosystems. These efforts are needed to prioritize conservation actions, evaluate the effectiveness of management interventions and help to pinpoint any drivers of population change in CMS-listed species.

Follow through on ecosystem restoration commitments, including those linked to the UN Decade on Ecosystem Restoration and Target 2 of the Kunming - Montreal Global Biodiversity Framework to ensure that at least 30% of degraded terrestrial, inland water, and coastal and marine ecosystems are under effective restoration by 2030. To support these efforts, develop and implement national restoration plans focussed on restoring and maintaining important habitats for migratory species.

Minimize the negative impacts of infrastructure projects on flyways, swimways and migration pathways for migratory species, with avoidance of impacts on critical sites for migratory species as a primary aim. Projects should be carefully planned from the outset in accordance with the relevant Environmental Impact Assessment and Strategic Environmental Assessment guidelines.

Overcome overexploitation

Ensure that national legislation fully and effectively protects CMS Appendix I-listed species from take, including by closely regulating any exceptions to the general prohibition of take and by participating in the CMS National Legislation Programme.

Assess the cumulative impact of harvest pressure on migratory species at the flyway and population level and use this information to manage levels of take. These aims could be supported by increasing efforts to collate data on both legal and illegal take at national and international scales.

Strengthen and expand collaborative international efforts to tackle illegal and unsustainable take, focussing on the main drivers of taking and on geographical areas identified as hotspots for illegal killing. Such initiatives could be based on the Task Forces established to tackle the illegal

killing of migratory birds. At the national level, multistakeholder action plans should be developed to agree priorities and foster collaboration to tackle this issue.

Reduce the harmful effects of environmental pollution

Promote widespread adoption of light pollution reduction strategies, including those outlined in the Light Pollution Guidelines for Wildlife endorsed by CMS Parties, focussing in particular on brightly lit areas that overlap with crucial habitat or migration corridors.

Restrict the emission of underwater noise in sensitive areas for marine species, including by making use of the CMS Family Guidelines on Environmental Impact Assessments for Marine Noise-generating Activities, and through the application of quieting technologies in key marine industries.

Addressing plastic pollution on land, at sea and in freshwater ecosystems by eliminating problematic and unnecessary plastics and by reducing the unnecessary use and production of plastics through regulations, incentives and practices.

Address the root causes and cross-cutting impacts of climate change

Deliver on international commitments to address climate change, including on pledges to reduce greenhouse gas emissions and enhance the removal of these gases from the atmosphere by maintaining and increasing carbon stocks in vegetation and soils. Carbon stocks should be managed in ways that align with internationally agreed biodiversity conservation goals.

Protect a network of sites important for future migratory species against the likely consequences of climate change by ensuring that there is sufficient connectivity between sites to facilitate dispersal and range shifts, and that this connectivity will persist in the face of projected climate impacts. Efforts to review the adequacy of the current network – and to expand this network – should fully integrate these projected impacts to ensure resilience.

Help migratory species adapt to a changing climate through targeted ecosystem restoration efforts, designed to improve habitat quality and connectivity and reduce the impact of extreme weather events, such as drought and thermal stress, by facilitating dispersal and range shifts ▪

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Pay-As-You-Throw program in the United States and lessons for Vietnam

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With the continuous increase in population and economic development, the amount of waste generated from societal activities has also significantly risen. This is not only an environmental issue but also affects community health and urban infrastructure. In this context, implementing a Pay-As-You-Throw (PAYT) or Volume-based waste fee model becomes more necessary than ever, as it not only encourages people to minimize waste generation but also motivates them to participate in recycling and reusing activities, thereby contributing positively to environmental protection and the building of a sustainable community.

Countries around the world such as the United States, Canada, Spain, Finland, South Korea, Japan, and Taiwan have implemented waste fee systems based on either volume or weight in various ways, depending on local conditions, legal regulations, and economic development. Volume-based or PAYT policies require households and businesses to pay based on the amount or waste volume generated.

In fact, PAYT has also been implemented in Vietnam for industrial or service waste generators (fees based on contracts between waste generators and collection/transportation and treatment companies based on the volume or weight of generation). However, for municipal solid waste (MSW), PAYT is a completely new approach regulated in the 2020 Environmental Protection Law.

This article will analyze the experience of implementing PAYT in the United States, one of the pioneering and successful countries in implementing this program.

1. PAY-AS-YOU-THROW IN THE UNITED STATES

Penetration of PAYT programs in the United States

In the United States, the PAYT system was first implemented in 1973 in Grand Rapids, Michigan. These programs grown from about 100 municipalities in the late 1980s to about 1,000 in 1993. In 2006, more than 7,100 municipalities had implemented PAYT, covering about 25% of communities in the US, including 30% of the largest cities in the country (US EPA, 2006). By 2011, nearly 9,000 municipalities had implemented PAYT programs (nerc.org, 2018). The PAYT program currently applying in the US leads to reduction of approximately 6.5 million tons of MSW per year in the United States (estimated reduction of 4.6 to 8.3 million tons of MSW from landfills annually). The largest number of programs is available in Minnesota, Iowa, Wisconsin, California, New York, Washington, and Pennsylvania, each with more than 200 municipalities. (US EPA, 2006).

The implementation of PAYT programs brings several benefits, such as minimizing waste generation rates and prolonging the lifetime of landfills. PAYT has shown effectiveness in encouraging households to dispose of less waste, with reduction rate ranging from 14% to 17%. The amount of recyclables in the United States has increased on average from 32% to 59% (epa.gov, 2016). The greatest strength of PAYT lies in its higher level of fairness, as individuals only pay for the amount of waste they generate rather than a flat fee as in conventional methods (such as per capita or per household charges). Additionally, applying this model helps localities forecast and ensure revenue from fee collection activities.

▲ *Waste containersn Seattle, Washington*

▲ *Garbagebagin Waterville, Maine*

The results of implementing PAYT in some municipalities

Municipalities	PAYT Program Start Date	Waste fee	Success: save cost and reduce waste
Grand Rapids, Michigan	1973	Prior to the 2012: the designated blue bags cost $3 per 32-gallon bag, or subscribe to weekly curbside collection with variable prices for rubbish bins. Since 2012: households were offered an option of three sizes (32, 54 or 96 gallons) embedded with an RFID chip associated with the resident's account.	Period 2006-2013: 28% net reduction in municipal solid waste and 76% increase in recycling tonnage.
Binghamton, New York	1991	The retail prices of the bags in 2024: $8.2/5 large bags (30-gallon), $5.2/5 medium bags (20-gallon), $2.5/5 small bags (10-gallon). Garbage bags placed for collection must weigh no more than 50 pounds.	In the first year: the amount of residential waste dropped to 13,389 tons, a reduction of over 48%. The recyclables recovered increased from 37% in 1991 to 41% in 2008.
Falmouth, Maine	1992	The retail prices of the bags: 64 cents/small bag (20-gallon), 91 cents/large bag (33-gallon). The 91 cents sticker is available for bulky items less than 35 pounds. The $4.8 tag is used for large items such as mattresses and sofas.	The recycling rate: a jump from 12% before the program to 21%. The bid price for collection in the first year was $116,000, compared to a bid of $146,000 for a traditional collection contract. A reduction of 900 tons of waste disposal per year.
Gainesville, Florida	1994	Residents pay $13.5, $15.95, $19.75 per month according to whether they place 35, 64, or 96 gallons of solid waste bins at the curb for collection.	The results of the first year of program: the amount of solid waste collected decreased 18%. The recyclables recovered increased 25%. The total disposal tonnage decreased from 22,120 to 18,116.
Seattle, Washington	1981	Monthly Residential Garbage Cart Rates in 2024: - Food and yard waste cart fee: Residents pay $7.3; $10.95; $13.95 according to whether they use 13, 32, or 96 gallons of waste cart. Extra yard waste: $7.05per brown craft bags, bundle or 32-gallon cart. - Garbage Cart Fee: $27.55, $33.75, $43.9, $87.65, $131.65 according to whether they place 12, 20, 32, 64 or 96 gallons of waste cart. Extra garbage: $13.6 per extra bag, bundle, or 32-gallon cart. - Recycling service is included in the garbage rate. There is no additional cost for recycling service for residents. The maximum weight for extra garbage is 60 pounds per unit.	In 1996: municipal solid waste generation has decreased to 49 % compared to 1981. The recyclables recovered increased from 26,8% in 1998 to 56,9% in 2017.

Source: US EPA (1997), John Abrashkin (2015), seattle.gov

PRICING SYSTEMS

Communities implementing PAYT need to select the type of pricing system they will use. There are three types of pricing systems used in a rate structure for PAYT program: proportional, variable rate, and multi-tiered pricing.

Proportional pricing

The proportional system creates the most direct relationship between waste amounts and price. Communities using this system charge residents a per-unit amount for each waste container they fill. For example, residents may pay $1.25 for each 32-gallon bag they set out. These are usually bag-or tag-based systems, with the bags sold at local retail stores or municipal offices.

Variable-rate pricing

In a variable-rate system, the per-unit price varies. Residents are usually billed based on their choice of subscription container size. For garbage they discard above their subscription level, residents must pay an additional fee. The price of any subsequent containers may increase or decrease, depending on the community's PAYT program goals. For example, a household that pays $1.50 per week for a 32 gallon bin subscription level might be charged $2.00 for each additional 32 gallon bin it sets out in weekly collections. Alternatively, the price of the additional container might be set at $1.00.Resident may pay the fee for extra garbage throwing away by purchasing bags or tags, or communities may count the additional set-outs at the time of collection and bill residents accordingly.

Multi-tiered pricing

Two-tiered or multi-tiered systems are sometimes used to help communities achieve revenue stability. Similar to the billing systems used by telephone and water utilities, residents subscribe to a base level of service, for which they pay a flat fee. These "first-tier" fees can be accessed through local taxes or through a regular monthly or quarterly charge, often included in a utility or other municipal bill. The fees can be used to cover the fixed portion of the cost of the community's solid waste program.

Residents then pay "second-tier" fees based on the amount of waste they throw away. Second tier fees may be priced in the same way as proportional or variable-rate systems. These fees are often used to cover the costs of collecting and disposing of additional amounts of waste. If the multi-tier fees are variable, they may increase or decrease for additional containers of waste.

ESTIMATING THE PER-CONTAINER PRICE

Planners review data on program costs and estimated amount of waste collected each year to calculate a price per container. Based on the approaches to rate structure design (looking at neighboring community's prices, preparing estimates, and using advanced rate-setting techniques) and the goals of the PAYT program (such as increasing recycling or keeping administrative costs to a minimum), the planners will decide which is best for their city or town.

Categories of program expenses could include: Administration costs (include public outreach, enforcement, and billing and customer service), collection costs (include collecting trash and recyclables, as well as labor and equipment costs and contract payments), and disposal and material handling costs (include fees for landfill disposal or waste combustion and costs for materials recovery facilities).

Planners will regulate waste fees through waste containers (variable bins, prepaid bags, and prepaid stickers or stamps). Collection crews are instructed to pick up only the amount of waste that is placed in the containers that have the appropriate tags or stickers attached to them.

CONTAINER OPTIONS

Variable bins

Under this system, the municipality offers households a set of standard, graduated bin sizes. These sizes range from approximately 10 to 90 gallons in capacity, although bins in the 30 to 60 gallon range are the most common. Typically, these systems operate on a subscription basis, under which residents choose in advance the size of the bin they wish to use (often called the subscription or service level). Bills based on service level or number of bins set out are then sent to households, usually monthly or quarterly.

Advantages: Greater revenue stability under subscription systems, since revenues vary only when residents change their service level. Compatibility with automated collection systems. Bins prevent litter from blowing and animals from scattering waste.

Disadvantages: Reduced waste reduction incentive, since residents are billed the same amount whether they fill their bin halfway or completely. Inventory and distribution system needed for bins. Requiring space to place bins at household. Billing system needed to collect revenues.

Prepaid bags

This system uses colored (or otherwise distinctively marked) standard-sized waste bags, usually 20 to 30 gallons in capacity. Residents purchase the bags from the solid waste agency through outlets such as municipal offices or retail stores.

Advantages: Residents save money whenever they put out fewer waste bags, creating a strong waste reduction incentive. Lower administrative costs, since residents pay directly for bags at municipal offices or local retailers. Lower implementation costs than bin systems; easy for residents to understand and use. The bags take up less space to put it at household than bins.

Disadvantages: Greater revenue uncertainty, since residents can buy many bags at once and then none for several weeks. Bags might not be compatible with automatic collection systems. Animals might tear bags and scatter waste.

Prepaid tags or stickers

Tags or stickers are designed to be used in tandem with different types of containers. Residents purchase tags or stickers from the solid waste agency through municipal offices or retail stores and attach them to their own garbage bags or bins. The tag or sticker specifies the size of the container it covers.

Advantages: Residents save money whenever they use fewer tags or stickers on their waste containers, creating a strong waste reduction incentive. Lower administrative costs, since residents pay directly for tags or stickers at municipal offices or local retailers. Lower implementation costs than bin systems. Residents can choose the types of containers they prefer.

Disadvantages: Greater revenue uncertainty, since residents can buy many tags or stickers at once and then none for several weeks. Need to establish and enforce size limits for each type of sticker. Tags and stickers may be stolen from waste containers. Need to offer residents stickers that will not fall off in rainy or cold weather.

In addition, the curbside municipal solid waste cart is embedded with an RFID chip associated with the resident's account. An RFID reader on the service arm of a semi automated truck records a curbside pickup every time the "smart cart" is collected, and the account is charged. Residents pre-pay for the service, and the city debits from their account each time the cart is emptied.

2. LESSONS FOR VIETNAM

In Vietnam, the 2020 Environmental Protection Law stipulates waste service charge based on volume or weight instead of the flat rate based on households or individuals. The PAYT program in the United States can provide some insights for Vietnam in facing waste management challenges and bringing about positive changes in waste collection, disposal, and recycling:

Firstly, develop and choose fee calculation methods and options. Three fee collection options (or a combination of them – or their combination) can be chosen for PAYT programs to collect fees for generated waste. The use of containers, designated bags, or pre-paid labels/tags should also be carefully selected to suit the specific conditions of each residential area.

Secondly, encourage waste reduction and recycling, especially in the context of population growth and the need for sustainable resource use.

Thirdly, improve the waste management system to enhance monitoring, supervision, and evaluation of waste management activities. PAYT requires an effective waste management system to monitor fee collection and waste disposal.

Fourthly, enhance cooperation and coordination between management levels to ensure the effective implementation of waste management programs, as PAYT often requires cooperation between local management levels.

Fifthly, support low-income groups. If not managed carefully, PAYT programs may increase costs for low-income households. Therefore, solutions should be considered to support low-income individuals (such as providing free waste bags or reducing bag prices for the elderly and low-income individuals) to reduce the negative impact on this group and ensure fairness for all social classes.

Sixthly, educate and raise awareness. In the United States, when PAYT programs were initially implemented, there were difficulties as residents perceived it as a new tax when it was separated and charged separately from the old fee system calculated along with rent or local property taxes. Therefore, PAYT is often combined with educational campaigns and communication to provide information and raise awareness about waste management. PAYT also requires active community participation, so Vietnam also needs to focus on educating the community about the importance of waste management and its impact on the environment, human health, as well as encouraging active participation from residents and stakeholders in building and implementing waste management program ▪

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Land degradation and solutions for desertification prevention, improving land quality, climate change adaptation in Vietnam

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World Environment Day (June 5th, 2024) and the World Day to Combat Desertification and Drought (June 17th, 2024) both have themes related to a global issue that affects the ecological security of the planet, poverty reduction, socio-economic stability, and sustainable development. The themes are "Restoring land, Combating drought and desertification" and "Managing and using land sustainably, Our heritage - Our future". It shows the concern of humanity about the environmental challenges, which are warned to be the greatest of all time, impacting all aspects of social life, livelihoods, and the environment.

▲ *Poster of World Environment Day 2024*

1. INTRODUCTION

Vietnam's land is at risk of decreasing both in quantity and quality due to the conversion of agricultural land to other purposes due to industrialization, urbanization, socio-economic development, national defense and security, new rural development, as well as land degradation. Many fertile areas are experiencing declining quality due to erosion, reduced soil fertility, drought, desertification, compaction, laterite formation, salinization, and acidification. The process and degradation are occurring in most natural geographic and economic regions of the country, both in agricultural and forestry lands. The area of degradation from low to high accounts for up to 15.07% of the total natural area, concentrated in the Midlands and Northern Mountains, North Central Coast, and Central Coast regions. Enhancing organic matter, controlling land use changes, sustainable land and water management are the strategies for combating desertification in Vietnam.

Many countries, including Vietnam, have developed national action program to combat desertification. On September 2nd, 2006, the Prime Minister issued Decision No. 204/2006/QD-TTg on the Promulgation of the National Action Program to Combat Desertification for the period 2006 - 2010 and orientation to 2020, in order to implement the UN Convention to Combat Desertification and concretize the orientation of the Sustainable Development Strategy in Vietnam (Vietnam's Agenda 21). Accordingly, the Ministry of

Agriculture and Rural Development is the lead agency for the National Action Program to Combat Desertification for the period 2006 - 2010 and orientation to 2020.

According to the Convention, desertification is land degradation in arid, semi-arid, and dry sub-humid areas due to various factors, including climate change and human activities. Land degradation is the process of reducing or losing the biological productivity and the ability to provide economic benefits of the land. Arid, semi-arid, and dry sub-humid areas are regions with an evaporation to precipitation ratio of about 0.05 to 0.60. In Vietnam, combating desertification means preventing the risk of land degradation, limiting the process of land degradation in semi-arid, arid, and dry sub-humid areas; restoring and rehabilitating degraded and wasteland by enhancing the role and responsibility of government agencies, along with promoting socialization so that households, enterprises, and social organizations participate in protecting and sustainably developing land, forest resources, preventing salinization, acidification, and mobile sand, and developing irrigation to improve livelihoods for people affected by desertification [3]. Initially, the Convention was only concerned with arid regions, but later it expanded its activities to prevent and combat land degradation.

According to Decree No. 204/2006/QD-TTg, the guiding principles for combating desertification include: (1) Combating desertification is a particularly important task, contributing to the sustainable management of natural resources, water resources and land, gradually increasing the income of the people, eradicating hunger, reducing poverty, and firmly resolving the task of resettlement and sedentarization. (2) The fight against desertification must be carried out in a scientific and effective manner, based on a unified and coherent system of state policies and laws, with a sense of succession and under the centralized and synchronous guidance of the Government; concretized through projects implemented by ministries, sectors, political-social organizations, and local People's Committees affected by desertification, mobilizing the attention and contribution of the whole society. (3) Expanding, diversifying, and multilateralizing international relations, but with a focus on concentrating investment and attracting investment from all economic sectors both domestic and foreign, strengthening the staff and absorbing modern technology, and inheriting suitable traditional experiences, contributing to the effective implementation of the National Action Program to Combat Desertification and multilateral environmental commitments (MEAs). (4) Closely combining economic development, social development, and environmental protection, ensuring national defense, security, and social safety and order, linking the National Environmental Protection Action Program as well as other national strategies and programs with the implementation of the United Nations Millennium Development Goals (MDGs).

2. CURRENT STATUS OF AGRICULTURAL LAND DEGRADATION IN VIETNAM

2.1. Current status of agricultural land in 2022

The data in Table 1 shows that forestry land and agricultural production land are the two main types of agricultural land, in which natural protection, special-use, and production forests account for 35.6% of the total agricultural land area. In agricultural production land, rice cultivation land and perennial crop land are the main types, with an area of 3,930,351 ha, accounting for 14.04%, and 4,919,721 ha, accounting for 17.57% of the total agricultural land area, respectively; these are the types of land that are crucial to the food security and livelihoods of rural people in both the delta and midland/mountainous regions. Meanwhile, the risk of desertification is emerging even in areas that were previously considered fertile, but due to unsustainable farming practices, land degradation has occurred.

2.2 Status of agricultural land degradation

2.2.1 Area of degradation

According to the General Department of Land Administration (2020), the agricultural land in Vietnam is mainly assessed as having a mild to moderate level of degradation, with the area of severe degradation only accounting for 4.14% of the total surveyed area and 3.64% of the total natural area. The areas with severe degradation are mainly located in Northern Midlands and Mountains (619,000 ha) and North Central Coast and Central Coast (455,000 ha). The area of moderately degraded land is mainly distributed in Northern Midlands and Mountains (1,839,000 ha) and North Central Coast and Central Coast (889,000 ha).

The severely degraded land is mainly found on the following types of land: 800,000 ha of unused land (accounting for 2.42% of the total natural land area), 293,000 ha of forestry land (accounting for 0.88% of the total natural land area), and 114,000 ha of agricultural production land (accounting for 0.34% of the total natural land area). The moderately degraded land is mainly found on the

following types of land: 1,655,000 ha of agricultural production land (accounting for 5.00% of the total natural land area), 1,367,000 ha of forestry land (accounting for 4.13% of the total natural land area), and 753,000 ha of unused land (accounting for 2.27% of the total natural land area).

The severely degraded forestry land is mainly found in the hilly and mountainous areas, which are predominantly affected by erosion, leaching, and a decline in soil fertility due to poor vegetation cover. These are the areas where the forests have been significantly degraded.

The degradation of aquaculture land is primarily due to saltwater intrusion in the coastal specialized farming areas, and in some areas, it is also caused by the unplanned conversion of rice cultivation land to brackish and saline aquaculture.

Table 1: Current status of agricultural land nationwide in 2022

Order	Land type	Code	Area (ha)	Percentage (%)
	Total agricultural land area	***NNP***	***28.002.574***	***100***
1	**Agricultural production land**	**SXN**	**11.673.357**	41,69
1.1	**Land for annual crop cultivation**	**CHN**	**6.753.636**	24,12
1.1.1	Rice cultivation land	LUA	3.930.351	14,04
1.1.1.1	Land dedicated to wet rice cultivation	LUC	3.190.965	11,40
1.1.1.2	Remaining land for wet rice cultivation	LUK	639.490	2,28
1.1.1.3	Upland rice cultivation land	LUN	99.895	0,36
1.1.2	Land for cultivation of other annual crops	HNK	2.823.285	10,08
1.1.2.1	Flat land for cultivation of other annual crops	BHK	1.053.522	3,76
1.1.2.2	Upland land for cultivation of other annual crops	NHK	1.769.763	6,32
1.2	**Land for perennial crops**	**CLN**	***4.919.721***	17,57
2	**Forestry land**	**LNP**	**15.467.658**	55,24
2.1	**Production forest land**	**RSX**	**8.025.301**	28,66
2.1.1	Production forest land is natural forest	RSN	**3.868.691**	13,82
2.1.2	Production forest land is planted forest	RST	***3.210.013***	11,46
2.1.3	Land being used for Conservation and Sustainable Use (RAX)	RSM	946.598	3,38
2.2	**Protective forest land**	**RPH**	***5.123.285***	18,30
2.2.1	Protective forest land is natural forest	RPN	4.016.676	14,34
2.2.2	Protective forest land is planted forest	RPT	599.697	2,14
2.2.3	Land being used for protection and development of protective forest	RPM	506.911	1,81
2.3	**Forest land with special-use forest designation**	**RDD**	**2.319.072**	8,28
2.3.1	Forest land with special-use forest designation is natural forest	RDN	2.083.974	7,44
2.3.2	Forest land with special-use forest designation is planted forest	RDT	104.658	0,37
2.3.3	Land being used for protection and development of RDM	RDM	130.439	0,47
3	**Land for aquaculture farming**	**NTS**	**783.930**	2,80
4	**Land for salt production**	**LMU**	**15.373**	0,05
5	**Other agricultural land**	**NKH**	**62.256**	0,22

Source: MONRE, 2022

2.2.2. Processes of land degradation

The land degradation processes across the country are not uniform, but rather depend on the characteristics of each region. They can be primarily categorized into 5 main degradation processes. Among these, degradation due to the processes of drought, desertification, and a decline in soil fertility are the most prominent.

Table 2. Current status of agricultural land degradation in 2020

Order	Degree of degradation	Area (ha)	Percentage (%)	Compared to the surveyed area (%)	Compared to the natural area (%)
1	Severe degradation	1.207.000	10,20	4,14	3,64
2	Moderate degradation	3.787.000	31,99	13,00	11,43
3	Mild degradation	6.844.000	57,81	23,49	20,66
	Total	**11.838.000**	**100,00**	**40,63**	**35,73**

Source: General Department of Land Administration, 2020

3. CAUSES AND SOLUTIONS FOR COMBATING DESERTIFICATION IN VIETNAM

3.1. Main causes of land degradation

Firstly, decline in soil fertility due to monoculture, intensive cultivation, and overuse of chemical fertilizers and pesticides, especially in concentrated, large-scale production areas with limited use of organic and microbial fertilizers, leading to soil acidification, loss of organic matter, and nutrient depletion.

Secondly, conversion of land use in coastal areas from rice fields and annual crops to aquaculture, leading to salinization and acidification in the Mekong Delta, especially in the provinces of Ca Mau, Bac Lieu, Soc Trang, and Tra Vinh.

Thirdly, shift cultivation practices (swidden agriculture) of ethnic minority groups leading to soil erosion and loss.

Fourthly, degradation and fragmentation of irrigation systems in the delta regions due to urbanization, industrialization, and new rural development.

Fifthly, in forestry, widespread deforestation, unsustainable logging practices (clear-cutting), and agricultural production on forestland, leading to soil erosion, deterioration of forest soil properties, and desertification, especially in Central Highlands and Northwest regions.

▲ *The Forest Department (Ministry of Agriculture and Rural Development) in coordination with the University of Forestry organized a rally and launched a tree planting campaign to respond to World Day to combat desertification and drought.*

3.2. Solutions to prevent desertification

Firstly, increase the application of organic fertilizers, utilize organic materials after harvesting to supplement soil organic matter, intercrop or rotate with leguminous crops and other nitrogen-fixing plants to improve soil health.

Secondly, strictly control land use changes in coastal areas, protect and plant mangrove forests along the coast in combination with investment in dyke systems, irrigation, and hydraulic structures to limit saline intrusion, leach acidic salts, and shift crop structures appropriately. Research saline-tolerant and climate-adaptive crop varieties.

Thirdly, strengthen inspection and monitoring in forest management, protection, and development, protect water resources, especially in Northwest

Table 3. Current status of degradation by land use type

Order	Land type	Area (ha)	Percentage (%)	Compared to the natural area (%)
1	**Agricultural production land**	**5.077.000**	**23,21**	**15,33**
1.1	- Severe degradation	114.000	0,52	0,99
1.2	- Moderate degradation	1.655.000	7,56	14,36
1.3	- Mild degradation	3.308.000	15,12	28,71
2	**Forest land**	**4.969.000**	**22,71**	**15,00**
2.1	- Severe degradation	293.000	1,34	1,97
2.2	- Moderate degradation	1.367.000	6,25	9,19
2.3	- Mild degradation	3.309.000	15,12	22,25
3	**Aquaculture land**	**93.000**	**0,43**	**0,28**
4	**Unused land**	**1.693.000**	**7,74**	**5,11**
	Total	**21.785.000**	**100,00**	

Source: General Department of Land Administration, 2020

and Central Highlands regions. Continue to apply support mechanisms and policies for people engaged in forestry through programs like payments for forest environmental services and carbon credit trading. Promote and guide techniques for sustainable cultivation of sloping lands such as terracing, agro-forestry, home gardens, and fixed shifting cultivation depending on slope levels to ensure sustainability.

Fourthly, invest in the development of high-tech agriculture, eco-agriculture, organic agriculture, experimental agriculture models, agri-tourism, and community-based agricultural learning on concentrated agricultural lands or interspersed in new urban areas, non-industrial, in association with new rural development to increase incomes and promote sustainable development.

Fifthly, survey, demarcate, and issue land use right certificates for forest land and land originated from state-owned farms and plantations to be allocated to ethnic minority groups lacking land. Establish agricultural land databases, develop digital maps of soil organic carbon in Vietnam, soil quality maps, and land degradation maps to monitor changes in soil organic matter content, soil quality, and land degradation ■

Table 4. Processes of land degradation

Order	Erosion process	Area (ha)	Percentage (%)	Compared to the natural area (%)
1	*Washout process*	13.358.000	29,67	40,33
2	*Process of soil fertility decline*	13.417.000	29,80	40,51
2.1	Severe decline	1526000	3,39	4,61
2.2	Moderate decline	4.409.000	9,79	13,31
2.3	Mild decline	7481000	16,61	22,58
3	*Process of drought and desertification*	16.773.000	37,25	50,64
3.1	Severe decline	1.449.000	3,22	
3.2	Moderate decline		0,00	
3.3	Mild decline		0,00	
4	*Process of conglomeration and lateriticization*	1156000	2,57	3,97
4.1	Severe conglomeration	194.000	0,43	0,58
4.2	Moderate conglomeration	369.000	0,82	1,11
4.3	Mild conglomeration	594.000	1,32	1,79
5	*Process of salinization*	197.000	0,44	0,59
5.1	Severe salinization	47.000	0,10	1,14
5.2	Moderate salinization	43.000	0,10	0,13
5.3	Mild salinization	107.000	0,24	0,32
6	*Process of acidification*	125.000	0,28	0,38
6.1	Severe acidification	81.000	0,18	0,24
6.2	Moderate acidification	17.000	0,04	0,05
6.3	Mild acidification	27.000	0,06	0,08
	Total	**45.026.000**	**100,00**	

Source: General Department of Land Administration, 2020

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Improve the quality of water environment of the Bac Hung Hai irrigation work system

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In recent time, environmental protection for river basins has received attention from the Party, the National Assembly and the Government, including environmental protection for the Bac Hung Hai irrigation work system (the Bac Hung Hai system). The Bac Hung Hai system is an important irrigation work, serving multiple purposes (agricultural and industrial production, business, people's livelihood) for 4 provinces and city: Bac Ninh, Ha Noi, Hung Yen and Hai Duong, the increasing amount of waste and wastewater discharged into the irrigation work system led to serious water pollution. Faced with the above situation, many positive and effective measures and solutions have been implemented to improve the quality of water environment of the Bac Hung Hai irrigation work system. This article summarizes results achieved, evaluates the current status and causes of pollution, and thereby proposes tasks and solutions appropriate to the current actual status to ensure the complete and thorough resolution to the water pollution problem for the Bac Hung Hai system.

1. CURRENT STATUS OF WATER SOURCE POLLUTION IN THE BAC HUNG HAI SYSTEM

Construction of the Bac Hung Hai system was started in 1958, the system has a total length of 232 km of main stream and over 2,000 km of branch streams and canals of all kinds to supply water for agricultural production and people's livelihood of 4 provinces and city (Ha Noi, Bac Ninh, Hung Yen and Hai Duong). Along with the process of urbanization and industrialization, the Bac Hung Hai system takes on the additional function of receiving domestic wastewater and wastewater from production, business, service establishments, hospitals, craft villages and livestock... with increasingly large traffic. The entire basin area is 192,045 ha, including 10 districts and cities of Hung Yen province with 79,480 ha; 7 districts and cities of Hai Duong province with 69,560 ha; 3 districts and towns of Bac Ninh province with 26,020 ha and 2 districts of Ha Noi city with 10,540 ha. Irrigation water is taken from Red river mainly through Xuan Quan sluice, from Thai Binh river through Cau Xe and Cau Cat sluices, and from Luoc river through An Tho sluice. Drainage water flows automatically through Cau Xe, An Tho, Cau Cat sluices and is actively drained through pumping stations combined with irrigation and drainage directly into large rivers in narrow areas along Duong, Luoc, and Thai Binh rivers.

Tasks of the Bac Hung Hai system include: (i) ensuring irrigation for 110,000 ha of cultivated land; creating a source of water supply for livestock and poultry farming, aquaculture in an area of 12,000 ha (ii) creating a source of domestic water supply for more than 3 million people and concentrated industrial parks, handicraft production establishments in an area of about 4,300 ha; (iii) draining water and preventing flood for an area of 192,045 ha, protecting people's livelihood, agricultural production and other production establishments; (iv) maintaining flow on river axes, contributing to reducing pollution, water resource depletion, and improving the ecological environment. The Bac Hung Hai Irrigation Works Exploitation One Member Company Limited under the Ministry of Agriculture and Rural Development (MARD) is responsible for managing 14 main focal works, 232 km of main canals and 491 km of main canal bank. Provincial-level irrigation works exploitation companies directly manage in-field works from level II canals, over 800 irrigation and drainage sluices covering an area of over 250 ha and thousands of kilometres of in-field canals.

In recent years, the Bac Hung Hai canal system has been degraded with sedimentation in many places, limiting the ability to carry water, leading to water often being stagnant and not circulating. The irrigation canal system also regularly receives a large amount of wastewater from daily activities of urban areas and concentrated residential areas; industrial wastewater from industrial zones - clusters, production, business and service establishments; animal husbandry, craft villages, healthcare... discharged directly into the system, causing serious pollution. According to data on periodic water quality developments in the provinces of Hung Yen, Bac Ninh, Hai Duong (frequency of 4-6 times/year) and 8 automatic surface water monitoring stations (Ha Noi city: 1 station; Hung Yen: 4 stations; Hai Duong: 3

stations); according to data from the Institute for Water and Environment, MARD (periodically from 2 to 6 times/year, at 10 points), the current water source status of the Bac Hung Hai system is polluted in both scope and level. Specifically, results of monitoring and analyzing water quality samples in the period of 2017-2022 show that over 90% of monitoring locations have one or more parameters with pollution of organics, nutrients, microorganisms... exceeding allowable limit of QCVN 08-MT:2015/BTNMT column B1 for irrigation and drainage or other uses (referred to as QCVN-08); over 90% of days have DO values that do not meet QCVN-08 and over 70% of days have $N\text{-}NH4^+$ and TSS values that exceed QCVN-08. Especially in the dry season, the level of water pollution in the Bac Hung Hai system increases significantly. In recent years (2021-2022), data at automatic monitoring stations have continuously recorded $N\text{-}NH4^+$ parameter values exceeding the limit during the entire rainy season. By early 2022, many river sections such as Nhu Quynh and Dien Bien river branches (belonging to Hung Yen province) and Cam Giang, Sat, Bui, Tu Ky, Cuu An, Dinh Dao rivers (belonging to Hai Duong province) are no longer able to receive water with $N\text{-}NH4^+$ parameter for irrigation and water transportation purposes; branches of Cau Bay river and Kien Thanh canal (Ha Noi city), Nhu Quynh, Ban Vu Xa, Cau Luong rivers and Tran Thanh Ngo, Dien Bien canals (Hung Yen province) and Cau Binh, Cau Coc rivers (Hai Duong province), the river section bordering Hung Yen and Hai Duong provinces are no longer able to receive water with COD and BOD_5 parameters for irrigation purposes...

On the other hand, the Bac Hung Hai system also has to receive a large amount of domestic wastewater from urban areas and concentrated residential areas; industrial wastewater from production, business and service establishments; wastewater from livestock and craft villages... and receive polluted water from rivers in the area (Cau Bay river of Ha Noi city; branches of Ban Vu Xa, Dinh Du rivers and Tran Thanh Ngo canal of Hung Yen province; Sat and Cuu An rivers of Hai Duong province;...), causing river pollution to increase.

Statistical data from the Directorate of Water Resources, MARD also show that the total amount of wastewater discharged into the Bac Hung Hai system in 2022 is about 438,899 m^3/day and night. In particular, wastewater discharged into the Bac Hung Hai system is mainly domestic wastewater from urban areas and concentrated residential areas (accounting for about 72%); remaining types of wastewater include: industrial wastewater generated from production, business and service establishments (about 18%) and agriculture, craft villages, healthcare (about 10%), specifically:

Domestic wastewater: Hung Yen province has 451 residential areas discharging wastewater with a flow of about 114,088 m^3/day and night; Hai Duong province has residential areas of 85 communes, wards and towns of 7 districts and cities discharging wastewater with a flow of about 153,215 m^3/day and night; Ha Noi city has 28 discharge points from residential areas that discharge wastewater directly into Cau Bay river with a flow of about 50,000 m^3/day and night. Most of these urban areas and residential areas have not yet invested in building and installing centralized domestic wastewater treatment systems to treat wastewater before discharging into the Bac Hung Hai system.

Industrial wastewater from industrial parks (IPs): 100% of operating IPs have centralized wastewater treatment systems, of which 18 IPs discharge wastewater into the Bac Hung Hai system with a flow of about 71,155 m^3/day and night (Hung Yen province has 7 IPs; Hai Duong province has 7 IPs; Ha Noi city has 2 IPs; Bac Ninh province has 2 IPs).

Wastewater from industrial clusters (ICs): There are a total of 51 ICs discharging wastewater into the Bac Hung Hai system, of which Ha Noi city has 5 ICs; Hung Yen province has 17 ICs; Hai Duong province has 23 ICs; Bac Ninh province has 6 ICs; 86.3% (46/51) of ICs have not yet invested in building centralized wastewater treatment systems to treat wastewater before discharging into the Bac Hung Hai system, 13.7% (7/51) of ICs have wastewater treatment systems (5 ICs in Ha Noi city, Luong Dien IC in Hai Duong province and Minh Khai IC in Hung Yen province).

Wastewater from craft villages: Hung Yen province has 59 craft villages; Hai Duong province has 47 craft villages; Bac Ninh province has 3 craft villages; Ha Noi city has not yet compiled statistics. Most craft villages have not yet invested in building centralized wastewater treatment systems. Some craft households pre-treat wastewater (settlement tanks, biogas) before discharging into the Bac Hung Hai system.

Wastewater from production, business, and service establishments outside IPs, ICs and craft villages: According to incomplete statistics, there are about 530 production establishments outside IPs, ICs, and craft villages discharging wastewater with a flow of 35,287 m^3/day and night and 108 establishments having wastewater treatment systems, of which Ha Noi city has 5 establishments, Hung Yen province has 107 establishments, Hai Duong province has 382 establishments, Bac Ninh province

has 34 establishments. In fact, there are still cases where establishments discharge untreated wastewater or treated wastewater but not meeting environmental technical standards into the Bac Hung Hai system.

Wastewater from livestock and aquaculture establishments: Hung Yen province has 2,608 livestock and aquaculture establishments; Bac Ninh province has 38 establishments, some of which are located between residential areas that have not yet invested in building environmental protection and wastewater treatment facilities or wastewater is not treated to meet allowed standards, discharging into the general drainage system of the area, then into the environment.

2. RESULTS OF ENVIRONMENTAL POLLUTION REMEDIATION FOR THE BAC HUNG HAI SYSTEM

To prevent and gradually reverse water pollution in the Bac Hung Hai system, in recent time, the MONRE has many guiding and urging documents issued such as: Decree No. 08/2022/NĐ-CP dated 10 January 2022 detailing a number of articles of the LEP; Circular No. 02/2022/TT-BTNMT on technical guidance on planning for surface water environmental quality management; Decision No. 2625/QĐ-BTNMT dated 10 October 2022 on controlling and treating water pollution in the Bac Hung Hai river system; Official Dispatch No. 5008/BTNMT-KSONMT dated 27 June 2023 requesting to continue organizing and implementing the Water pollution control and treatment plan in the Bac Hung Hai system...

The MONRE has coordinated with functional sectors, provinces and city: Bac Ninh, Hai Duong, Hung Yen and Ha Noi to inspect and examine the compliance with legislations on environmental protection of production, business and service establishments having waste discharged into the Bac Hung Hai system. According to the report of the MONRE, from 2018 to 2022, the Vietnam Environment Administration of the MONRE and competent agencies of the provinces and city: Ha Noi, Bac Ninh, Hai Duong and Hung Yen conducted inspections and examinations at 835 establishments operating in the provinces of the Bac Hung Hai system; sanctioned 427 establishments with a total amount of over 25.7 billion VND.

The Police Department for Countering Environmental Crimes and public security forces of 4 provinces and city focused on organizing 6 peak rounds of inspection and handling of 562 cases of violation of environmental protection legislations with a total amount of about 19.2 billion VND; at the same time, made a list of main waste discharge points and prepared management and monitoring records for establishments with large waste sources or causing environmental pollution.

Infrastructure investment has been paid attention to, regarding wastewater generated from industrial production activities, 100% of IPs in 4 provinces and city that discharge wastewater into the Bac Hung Hai system have invested in building centralized wastewater treatment systems. However, for wastewater generated from ICs, craft villages, and livestock farms, most of them have not yet invested in building wastewater collection and treatment systems according to regulations.

For domestic wastewater collection and treatment activities, Hung Yen city has had a wastewater collection and treatment system with a capacity of 6,300 m^3/day and night. Hai Duong city has built a wastewater treatment system with a capacity of 13,000 m^3/day and night and is completing the basic design of the project to build a collection pipe to separate urban wastewater to a wastewater treatment station with a capacity of 12,000 m^3/day and night. Bac Ninh province has directed relevant departments, sectors, district and town People's Committees to research, report, propose plans, investment funds and agree on locations to build centralized wastewater treatment stations in Thuan Thanh town, Gia Binh and Luong Tai districts. Ha Noi city has planned for the period of 2021-2025 to invest in building wastewater treatment plants in Phuc Dong, An Lac, Dong Du, Phu Thi to treat urban wastewater with a total capacity of about 70,000 m^3/day and night.

Besides, Ha Noi city has installed an automatic and continuous surface water environmental monitoring station on Cau Bay river (at the Am pumping station location in Ngoc Dong village, Da Ton commune, Gia Lam district). Hai Duong province has installed 4 stations and Hung Yen province has installed 4 automatic and continuous water environmental monitoring stations.

Along with that, local authorities promote propaganda and raise awareness of people as well as the business community about environmental protection and water quality protection in the Bac Hung Hai system; guide businesses to focus on investing in wastewater treatment works that meet environmental protection requirements...

3. SOME REMAINING PROBLEMS AND CAUSES

Although some above results have been achieved in controlling and treating water source pollution in the Bac Hung Hai system, the water source pollution status is still complicated, and some areas are still polluted locally with main causes as follows:

Urban areas, concentrated residential areas and rural areas do not have wastewater collection system or treatment plant, most of wastewater is being discharged directly into the environment; 86% of industrial wastewater from ICs is not treated; most of craft villages and livestock households do not have wastewater collection and treatment systems. This is the main and direct cause of water pollution.

The phenomenon of sedimentation in the river bed, encroachment on the river bed and river banks, throwing garbage, littering, and waste into the river still recurs, causing flow congestion, stagnant water, and no circulation. In addition, during the dry season of the year, the water source to supplement the Bac Hung Hai system is lacking, because the water level of the Red river at Xuan Quan sluice is lower than the design level, the Bac Hung Hai system is completely just a canal circulating wastewater discharged from residential and industrial activities in the area, causing water pollution more serious.

The awareness of some businesses and people is still low, they do not strictly comply with environmental protection legislations, there are still incidents of discharge of untreated wastewater or treated wastewater not meeting technical requirements in accordance with environmental protection regulations, this is the cause contributing to water pollution in the Bac Hung Hai system.

Investment projects to build centralized domestic wastewater treatment plants often have large investment costs, so many projects lack investment resources, leading to slow implementation.

4. SOLUTIONS FOR ENVIRONMENTAL POLLUTION REMEDIATION FOR THE BAC HUNG HAI SYSTEM

To completely solve the environmental pollution status of the Bac Hung Hai system, improve and restore the environment and landscape ecosystem of polluted river sections, returning the original and inherent environment of the Bac Hung Hai system, on 9 August 2023, the Government Office issued Document No. 315/TB-VPCP announcing the Conclusion of Deputy Prime Minister Tran Hong Ha at the Conference on the results of remedying environmental pollution in the Bac Hung Hai irrigation works system, assigning tasks to each ministry, sector and local authority to organize the implementation with a number of key solutions and tasks such as:

Firstly, the group of solutions and tasks on planning: Focus on completing the master plan of 4 provinces and city on the Bac Hung Hai system, in particular integrate relevant master plans, clearly identify solid waste treatment areas and centralized domestic wastewater collection and treatment systems in accordance with the orientation in regional master plan, national environmental protection master plan, national sectoral environmental protection master plan according to regulations. Arrange enough land fund to implement technical infrastructure for environmental protection according to approved master plans.

Secondly, perfecting mechanisms and policies: Research and propose mechanisms and policies to mobilize all resources, especially socialization and investment in the form of public-private partnerships in centralized solid waste and wastewater treatment works; review all national sectoral technical regulations (QCVN) related to wastewater and drainage; on that basis, research, propose the development and promulgation of QCVN on treated wastewater for different uses, including the purpose of using treated wastewater to replenish water sources for rivers, canals and ditches... helping maintain flow, reduce and improve water pollution.

Thirdly, investment in and building technical infrastructure for environmental protection: Concentrate investment resources on building centralized domestic wastewater collection and treatment works, ensuring wastewater generated in the area is fully collected and treated, meeting QCVN requirements before discharging into the Bac Hung Hai system; invest in automatic and continuous wastewater and surface water monitoring systems, especially for wastewater sources with large discharge volumes on the Bac Hung Hai system; environmental monitoring data must be transmitted, updated, and stored to relevant competent agencies for exploitation and use according to regulations.

Fourthly, management, control and monitoring of waste sources: Build a shared database to manage waste sources discharged into the Bac Hung Hai system to serve the management, control and monitoring of waste sources; develop and organize the implementation of management, control and monitoring plans for each waste source according to the principle of which level, unit approves and grants the permit to discharge

wastewater into the waste source (environmental permit), that level, unit must manage, control and monitor the permitted waste sources; do resolutely not grant investment licenses or environmental permits to projects and establishments that do not meet environmental protection requirements, especially projects and establishments that do not have wastewater treatment measures or works to ensure wastewater treated meeting the QCVN before discharging into the Bac Hung Hai system.

Fifthly, the work of inspecting, examining and handling environmental violations: Continue to strengthen the work of inspecting and examining the compliance with legislations on environmental protection; prevent and combat environmental crimes and handle environmental violations by organizations and individuals discharging wastewater into the Bac Hung Hai system and its tributaries; strictly handle violations. At the same time, thoroughly apply measures to remedy the consequences of violations, suspend waste discharge activities and require upgrading and completion that wastewater treatment works must ensure meeting environmental protection requirements according to regulations.

Sixthly, propaganda and communication to raise awareness of environmental protection: Strengthen propaganda and communication to raise awareness of environmental protection, especially the provisions of the LEP 2020 and documents guiding implementation so that each business and citizen can understand the legal regulations on environmental protection and be deeply aware of their roles and responsibilities in environmental protection; maximize the role of socio-political organizations, unions, and residential communities in joining hands for environmental protection; resolutely fight and not let acts of discharge of waste polluting the environment of the Bac Hung Hai system take place in the area.

Specific tasks:

- *Ministry of Natural Resources and Environment:* Preside and coordinate with relevant agencies to advise on the development and submission to the Prime Minister for consideration and promulgation of the Prime Minister's Directive on "Some urgent solutions to strengthen controlling and treating river basin water environmental pollution", considered for promulgation in the third quarter of 2023; select the Bac Hung Hai system as a pilot model to handle and have plans and solutions to completely resolve the environmental pollution of rivers flowing through urban areas and large cities across the country; urgently develop, submit for promulgation and organize the implementation of the surface water environmental quality management plan for the Bac Hung Hai system according to the provisions of the LEP 2020; continue to promote inspection and examination of compliance with environmental protection legislations.

- *Ministry of Public Security:* Continue to direct the Police Department for Countering Environmental Crimes and public security forces of 4 provinces and city to promote the prevention, detection and fight against environmental crimes; strictly handle acts of discharge polluting the environment in the Bac Hung Hai system; strengthen examination and reconnaissance to promptly prevent and immediately handle acts and activities of establishments that discharge waste in contravention of regulations polluting the environment.

- *Ministry of Agriculture and Rural Development:* Review and comprehensively evaluate the current status and effectiveness of irrigation works; develop projects, plans, arrange capital sources and organize the implementation of dredging, repairing and upgrading works of the Bac Hung Hai irrigation system; review and develop operating procedures for the Bac Hung Hai system in a synchronous, unified and rhythmic manner, ensuring the maintenance of minimum flow according to regulations. In the immediate future, focus on researching and proposing solutions in the direction of investing in field and mobile pumping systems in suitable locations to promptly replenish water sources into the Bac Hung Hai system in the dry season of 2023.

- *Ministry of Construction:* Research, develop and propose competent agencies to promulgate regulations on functional zoning planning in urban areas that integrate centralized wastewater treatment system planning; guide and solve problems that arise in localities during the process of investing in building, upgrading and renovating technical infrastructure systems for collecting, treating and draining wastewater from urban and concentrated residential areas on the Bac Hung Hai system according to regulations; develop and promulgate economic and technical norms for the collection and treatment of wastewater in urban and concentrated residential areas.

- *People's Committee of 4 provinces and city:* Urgently review and submit to the Prime Minister for consideration and approval of provincial master plan for the period up to 2030 and vision to 2050, in which, pay attention to solid waste treatment areas, centralized wastewater

collection and treatment systems that must be integrated into provincial master plan according to regulations; develop and approve investment plans and roadmaps to build, upgrade, renovate and expand the system of rainwater collection works separate from the wastewater collection and treatment works on the Bac Hung Hai system according to regulations. Specifically:

+ Concentrate resources to implement investment projects to build concentrated domestic wastewater treatment plants from medium-term public investment sources (period of 2023-2025, 2026-2030), ensuring that by 2030, collect and treat all domestic wastewater generated in the area to meet QCVN before discharging into the environment. Prioritize investment projects for urban areas and concentrated residential areas having waste directly discharged into the Bac Hung Hai system. Particularly for Ha Noi city, it is necessary to concentrate and urgently mobilize all resources to accelerate the implementation of investment projects to build centralized domestic wastewater treatment plants in Long Bien and Gia Lam districts to collect and treat all domestic wastewater generated in the area before discharging into Cau Bay river, then into the Bac Hung Hai system.

+ Develop a plan to deploy a pilot model to completely resolve water environmental pollution in the Bac Hung Hai system.

+ Invest in field and mobile pumping systems in suitable locations to promptly replenish water sources into the Bac Hung Hai system in the dry season of 2023.

+ Resolutely not grant investment licenses or environmental permits to projects and establishments that do not meet environmental protection requirements according to regulations, especially projects and establishments that do not have environmental protection measures or works meeting environmental protection requirements, and do not ensure that wastewater is treated to meet QCVN before discharging into the Bac Hung Hai system.

+ Continue to promote inspection and examination of compliance with environmental protection legislations, strengthen prevention, detection and fight against environmental crimes, focus on projects and establishments that discharge waste into the Bac Hung Hai system, strictly handle violations according to regulations.

+ Strengthen communication work, raise people's awareness of environmental protection, responsibility, and importance of protecting water resources of river basins including the Bac Hung Hai system.

+ Build a shared database to manage all waste sources generating wastewater discharged into the Bac Hung Hai system, that effectively serves management, control and monitoring; in which local authorities conduct surveys, collect and synthesize information and data to build a shared database.

+ Review and develop operating procedures for the Bac Hung Hai system in a synchronous, unified, and rhythmic manner, ensuring the maintenance of minimum flow according to regulations.

+ Review provincial master plans to ensure full integration of centralized wastewater collection and treatment systems in the area in accordance with orientations in regional master plan and national environmental protection master plan according to regulations.

+ Implement regulations on public-private partnerships for investment in construction and operation of centralized wastewater collection and treatment systems, especially in urban areas and concentrated residential areas; determine prices of wastewater treatment services appropriate to people's ability to pay, have a roadmap, ensure correct and complete calculation of costs, and ensure attraction and encouragement of socialized capital in investment in construction and operation of centralized wastewater treatment works.

+ Review local technical regulations related to wastewater, research and promulgate local technical regulations on wastewater with stricter regulations than QCVN.

5. RECOMMENDATIONS

The MONRE requests ministries, sectors and local authorities, based on their assigned functions and tasks, to develop and implement plans, and report results to the MONRE for synthesis and reporting to the Prime Minister.

Recommend to the Government and National Assembly to consider, authorize the development and submission for approval of the National target program on pollution remediation and environment improvement, which includes investment in construction and operation of centralized wastewater collection and treatment systems, especially in craft villages, urban areas, and concentrated residential areas ▪

Developing the carbon credit market for Vietnam's road transport sector

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1. INTRODUCTION

In Vietnam, the activities of the transport sector in general and road transport services in particular contribute significantly to economic growth and quality of life. The gross domestic product (GDP) of transport and warehousing activities has increased in recent years and reached 5.4% of the country's total GDP in 2022. Due to, demand for passenger and cargo transport increased with the average annual increase of 2.9% and 10.2% in the period of 2015-2022, respectively. The road sector accounts for a large proportion of transport with 91.8% of total passenger volume and 79.8% of total cargo volume by 2022 (General Statistics Office, 2023). Fuel used for vehicles is mainly gasoline and diesel. Vehicles used in this sector are very diverse including motorbikes, cars (taxi), buses, passenger cars, trucks (light, medium and heavy).

Besides making an important contribution to economic growth, the energy consumption demand of the transport sector also accounts for a significant proportion. Only considering transport service activities, total energy consumption ranked third in the economy. In 2000, the energy consumption was 830.9 ktoe (1.7 times higher than in 1996); followed by 2,633.1 ktoe in 2007 (3.2 times higher than in 2000); it was 4,883.3 ktoe in 2012 (1.85 times more than in 2007) and in 2018 it was 9,733.5 ktoe (2 times more than in 2012). The average annual growth rate is approximately 14.5% in the period of 1996 - 2018. The main fuels used in the transport sector are gasoline and diesel, accounting for 99% in the past 22 years.

In the transport service sector, road transport services play an important role and consume the largest amount of energy. The energy consumption of the road transport sector was 48.2% (equivalent to 238.2 ktoe) in 1996; 29.7% (equivalent to 247.2 ktoe) in 2000; 62.2% (equivalent to 1,637.1 ktoe) in 2007; 58.4% (equivalent to 2,851.4 ktoe) in 2012 and 60.0% (equivalent to 5,836.8 ktoe) in 2018 (Pham Thi Hue, 2021). If mitigation solutions are not applied, this emission rate will increase to 71% by 2040 (World Bank, 2013).

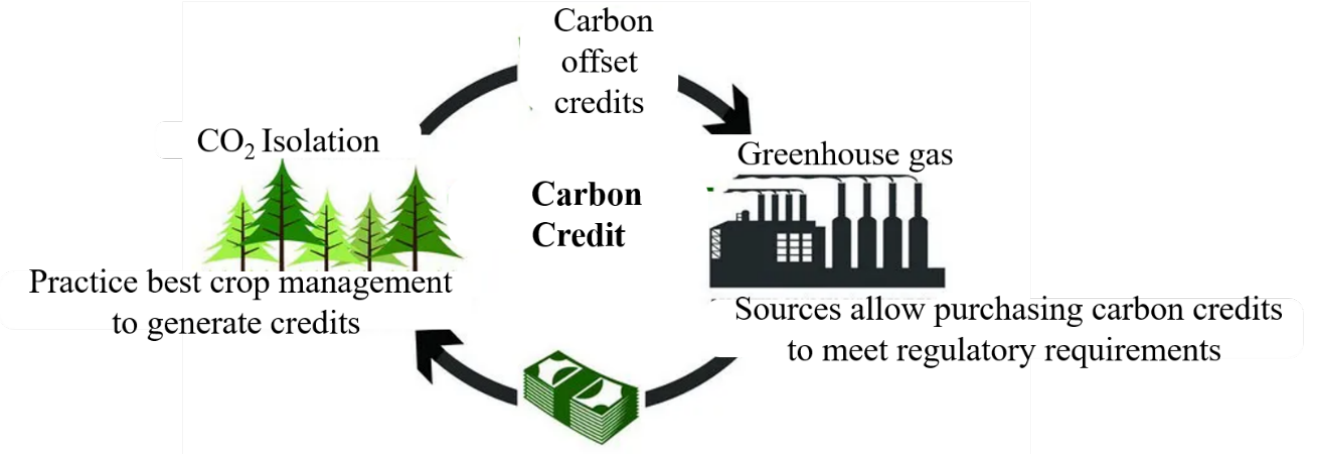
Due to CO_2 emissions content in the road sector is the highest, so Vietnam needs to apply greenhouse gas (GHG) emissions reduction solutions. At the same time, Vietnam will soon build processes, roadmaps and solutions for the carbon credit market development to achieve the goal of bringing net emissions to "zero" by 2050 and improving the economic efficiency of the sector.

2. CONCEPT OF CARBON CREDIT MARKET

The carbon credit market originated from the United Nations Kyoto Protocol on Climate Change, adopted in 1997. According to this organization, surplus countries have the rights in order to sold or purchased them from countries. Since then, a new type of commodity has appeared widely in the world, namely GHG emission reduction/absorption certificates, transactions collectively known as carbon trading and exchange, forming a carbon market (Figure 1).

The carbon market has developed strongly in European, American and Asian countries with two main types of markets such as mandatory carbon markets and voluntary carbon markets. In particular, the mandatory carbon market is a market in which carbon trading is based on the commitments of countries in the United Nations Framework Convention on Climate Change (UNFCCC) to achieve GHG reduction goals. The voluntary carbon market is a market based on bilateral or multilateral cooperation agreements between organizations, companies or countries. Credit purchasers engage in transactions on a voluntary basis to meet environmental, social and corporate governance (ESG) policies to reduce their carbon footprint.

The market price of carbon credits in each country is very different: In 2022, the price of one carbon credit was 9.29 USD/ton in China while it is 87 USD/ton in Europe as well as 40 USD/ton in Australia. Meanwhile, the market prices have been fluctuated sharply, from the lowest of 15 USD/ton to the highest of 96 USD/ton at Europe since 2020. Carbon pricing is an approach to effectively reduce GHG emissions through the use of market mechanisms to transfer the costs of emissions to emission sources according to the "polluter pays" principle". Accordingly, emission facilities must be responsible for paying the costs due to releasing GHG into the atmosphere (Pham Hong Quan, 2023).



▲ *Figure 1. Carbon credit market model*

Source: Pham Hong Quan, 2023

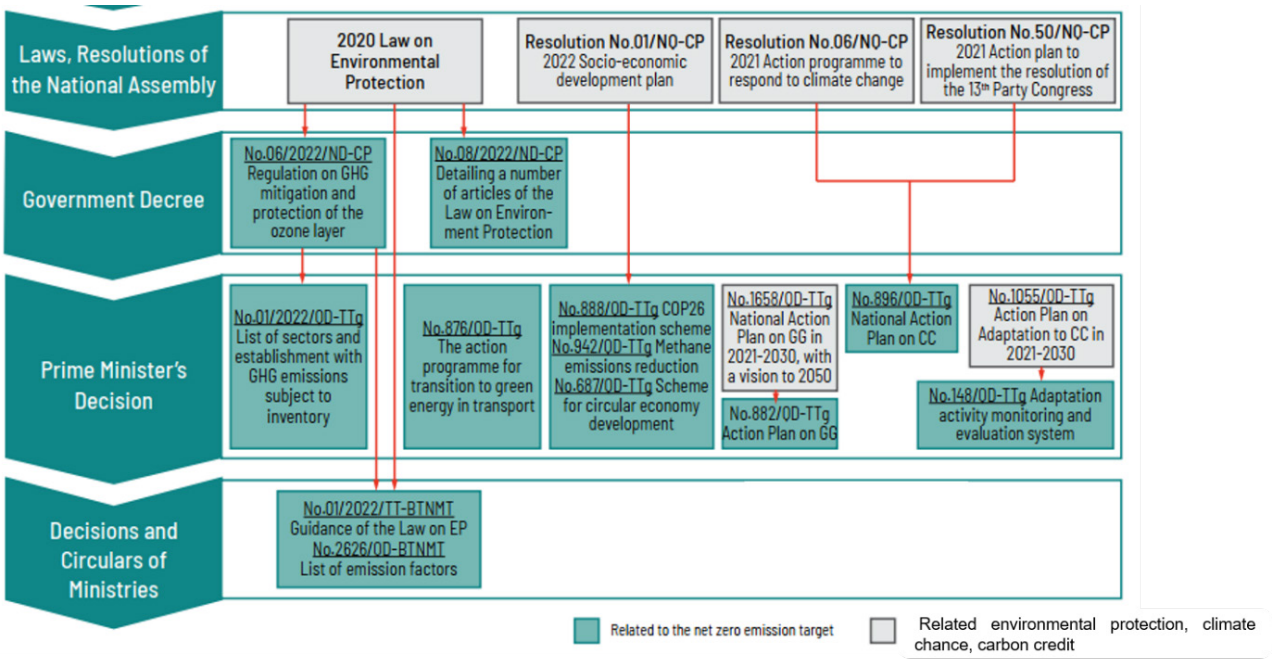
3. OPPORTUNITIES AND CHALLENGES FOR DEVELOPING CARBON MARKETS FOR VIETNAM'S ROAD TRANSPORT SECTOR

About opportunities: The road transport sector plays an important role in implementing national GHG emission reduction goals and achieving climate goals. Because through a circular, sustainable and low-carbon production and business model, this field will directly contribute to reducing GHG emissions, towards green production - consumption and emissions goals. net is "0". According to the Nationally Determined Contribution Report 2020 (NDC, 2020), updated NDC 2022 (NDC, 2022) Vietnam has increased its unconditional emission reduction contribution to 2030 from 9% to 15.8%. and conditional contributions from 27% to 43.5%. To achieve the above goals, in recent years, the transport sector has proposed and implemented a Strategy for efficient use of energy, which focuses on 4 main groups of solutions for the road transport sector, including energy efficiency (limiting fuel consumption for motorbikes and cars; improving road vehicle emission standards; increasing truck load factors); converting from private to public means (developing the regular bus system, developing the rapid bus system, developing the metro system); conversion from road transport to waterway and rail (conversion from road to inland waterway, conversion from road transport to coastal transport, conversion from road to rail); fuel/energy conversion for the vehicle fleet (promoting the use of biofuel, using electric motorbikes, electric cars, electric buses, electric trucks) (GIZ and UNDP, 2022).

In addition, legal documents on GHG emission reduction and carbon credit market issued by Vietnam are the legal basis for road transport enterprises to implement, specifically: In Article 139, The Law on Environmental Protection 2020 stipulates the organization and development of the domestic carbon credit market, in which the Agency is tasked with setting the total quota and determining the quota allocation method to be applied in the carbon credit exchange system (ETS) is the Ministry of Natural Resources and Environment. On that basis, on January 7th, 2022, the Government continued to issue Decree 06/2022/ND-CP detailing the mitigation of GHG emissions, protecting the ozone layer, as well as specifying carbon credit market. The Decree also stipulates that the carbon credit exchange will be established and tested from 2025 and officially put into operation in 2028; Decision No.01/2022/QD-TTg promulgating a list of GHG-emitting sectors and facilities that must conduct GHG inventories; Circular No.01/2022/TT-BTNMT details the implementation of the Law on Environmental Protection in response to climate change.

Along with that, the Government also issued Decision No. 876/QD-TTg dated July 22th, 2022 on approving the Action Program on green energy conversion and reducing carbon and methane emissions for the transport sector (Figure 2). Currently, amount of 70 per 1,912 enterprises in the road transport sector are required to inventory and report their GHG emissions inventory. However, the inspection and examination will be carried out regularly to provide information to the related ministries. Participating in the carbon market not only contributes to improving reputation but also performs well the task of environmental protection.

Some challenges: The Vietnam Energy Outlook Report 2021 has just been announced by the Department of Electricity and Renewable Energy (Ministry of Sector and Trade) and the Danish Energy Agency,



▲ *Figure 2. Diagram of the current legal document system related to GHG emission reduction in the road transport sector (GIZ, 2023)*

predicting that the number of cars in our country in the period 2030-2050 will increased 3 times and 8.5 times respectively compared to 2020. This is also a challenge for the transport sector. In order to reduce GHG emissions, the transport sector needs reform policies, drastic measures and incentive mechanisms to gradually eliminate vehicles using polluted fuels.

At present, the legal framework regulating the carbon market for road transport is still lacking and not specific. The work of implementing GHG emission inventory reports for road transport businesses and establishments according to Decree No. 06/2022/ND-CP dated January 7th, 2022 is still difficult. According to statistics, the proportion of enterprises in the road transport sector that understand and carry out GHG inventories is very low, less than 1% compared to the number of 1,912 establishments and businesses required to conduct GHG inventories.

In addition, when participating in the carbon credit market, the road transport sector will face challenges in terms of funding. In addition, the appraisal, registration and verification of carbon credits, if not specifically guided, will cause inadequacies for establishments and businesses when implementing.

4. SOLUTIONS TO DEVELOP THE CARBON CREDIT MARKET FOR VIETNAM'S ROAD TRANSPORT SECTOR

Firstly, in terms of mechanisms and policies

The field of road transport contributes the largest amount of emissions in the transport sector, so it is necessary to develop specific mechanisms and policies for this field. Policies to participate in the carbon market need to be based on general regulations of the Government, specifically regulations first need to be made for businesses dealing in transport vehicles (passenger cars, buses, trucks). Then, for businesses dealing in service activities such as warehousing, repair activities and finally for the activities of individuals (vehicle owners, service-activity owners).

The State needs to promulgate a number of mechanisms and policies for road vehicles, including: controlling the increase of vehicles causing urban traffic congestion such as passenger cars and light trucks; promoting the production and use of low-carbon vehicles such as electric vehicles, vehicles using hydrogen fuel and biodiesel fuel; issuing policies to encourage organizations, businesses and individuals to participate in the carbon market such as using vehicles and energy to reduce emissions and participating in planting trees to earn carbon credits.

In addition, it is necessary to promulgate regulations that limit the amount of emissions prescribed for each type of vehicle to gradually decrease over time to achieve long-term and short-term goals (short-term goals can be implemented in 5 years, 10 years and long term is over 20 years).

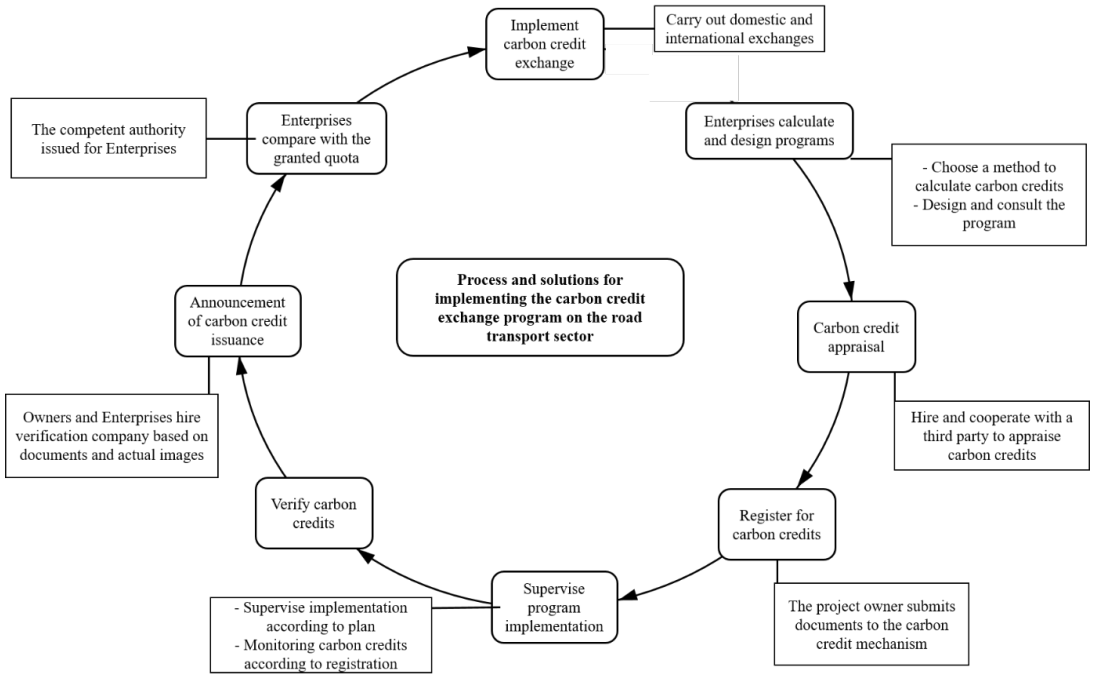
Regarding carbon credit quota allocation: Based on the situation, scale and specific activities, allocate carbon credit quotas appropriately for applicable organizations and individuals.

Regarding the carbon credit exchange mechanism, strengthen the construction of a carbon credit exchange mechanism for internal and external sectors, creating a unified operating mechanism and avoiding non-transparent trading. To limit this existence, the State management agencies in charge need to strengthen supervision and develop penalty regulations as a basis for implementation. The carbon credit exchange mechanism is exchanged between similar subjects such as business owners, organizations with the same type of activity (vehicle production, fuel, transport service business), and individuals with similar activities (vehicle use). The exchange and purchase of carbon credits is regulated with the participation of a third party to ensure responsibility and fairness.

Secondly, the technical solutions:

To effectively implement the carbon credit exchange program for the road transport sector, it is necessary to follow the following process (Figure 3):

Regarding implementation the route: Based on Decree No. 06/2022/ND-CP dated January 7th, 2022 regulating GHG emissions mitigation and ozone layer protection, the route for implementing carbon credits in the road sector including two phases as follows:



▲ *Figure 3. Process and solutions for implementing the carbon credit exchange program*

In the period 2024 - 2027: Conducting development of regulations on carbon credit management, activities of exchanging GHG emission quotas and carbon credits; develop a process for exchanging carbon credits; develop regulations for operating the carbon credit exchange and pilot implementation; establishing and organize pilot operation of a carbon credit exchange from 2025; implementing capacity building activities and raise awareness about carbon market development; learning about the experience of carbon markets in the road transport sector in some countries around the world.

Starting from 2028: Developing regulations on activities connecting and exchanging domestic carbon credits with regional and world carbon markets; operates a carbon credit trading floor.

The Ministry of Transport will issue documents regulating, directing and guiding the implementation of contents related to appraisal, registration, supervision and verification for the transport sector in general and the road sector in particular.

Enterprises in the road sector need to carry out GHG testing; participating in implementing carbon credit projects; participating in training courses on carbon credits.

Thirdly, propagating and guiding for implementation of GHG reduction and participation in the carbon market for road transport enterprises.

Authorities coordinate with scientists in order to organize training for road transport enterprises on knowledge about GHG emission reduction; it is limited and allocated for the carbon credit exchange. At the same time, organizing guidance on the route and reporting procedures as well as participating in the domestic and foreign carbon credit exchange market when eligible. In addition, through the above solutions, State Management Agencies also need to issue mechanisms and policies for supporting timely capital, financial and human resources. This is very good for Enterprises and State Management Agency in order to participate in the domestic and international carbon credit market on the coming time ▪

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Tram Chim National Park is a typical wetland ecological standard model of the Dong Thap Muoi region in the Mekong Delta (Mekong Delta) and was upgraded from Tram Chim Wetland Nature Reserve according to the Decision No.253/1998/QD-TTg dated December 29th, 1998 of the Prime Minister. With a total core area of 7,313 hectares, Tram Chim National Park is considered one of the places with ecological importance and biodiversity including 130 plant species; 130 species of fish and other amphibians and reptiles, more than 230 species of birds, including the rare and endangered species: sarus crane.

THE RETURN OF THE SARUS CRANE IN TRAM CHIM

Tram Chim National Park was recognized as the 4th Ramsar site in Vietnam in 2000 and in the world in 2012. Tram Chim National Park became one of the wetlands of international importance in preserving habitats of species water bird. Compared to other special-use forests in the Mekong Delta, Tram Chim National Park has the largest number of bird species, especially the sarus crane (Grus antigone), a rare bird species of global importance.

However, the sarus crane is in danger of extinction, recorded in the IUCN Red List. According to the International Crane Federation (ICF), it is estimated that in 1990, there were about 1,100 sarus crane individuals and remained around 900 until 2002. After that, there was a decline of about 1% each year, until 2013 there were about 850 individuals. However, from 2014 to 2019, sarus cranes declined by 72%, with only 234 birds remaining, and in 2020, it is estimated that there will be only 179 birds left.

Sarus cranes usually come to visit Tram Chim National Park from late January to mid-May every year. According to statistics of Tram Chim National Park, in 2015 the number of cranes was 21; in 2016, there were 14 individuals; in 2017, there were 9 individuals; in 2018 and 2019, there were 11 individuals. In 2020, the cranes did not return; In 2021, 3 birds returned, then absent until now, 4 birds have returned in subdivision A5 of Tram Chim National Park. The number of sarus crane coming to Tram Chim is decreasing due to many different reasons, mainly due to climate change and the impact of the ecological environment; the flood water is low, unable to wash away food baits, and also reduces the amount of fishery that is the main food of birds.

Currently, Tram Chim National Park has also sent professional staff to monitor 24/24 in subdivision A5 and other subdivisions, where cranes used to feed, in order to monitor and have appropriate management orientation. At the same time, assign security forces to regularly patrol around the dikes to prevent people from catching bees and exploiting products that affect the living environment of sarus cranes. The garden has added an additional food source (rice) for the cranes when the crane population has stabilized, in order to attract more and more cranes. Along with that, technical measures are implemented to restore the ecosystem, creating favorable conditions for cranes to come and feed.

At the end of 2023, the People's Committee of Dong Thap province approved the project to conserve and develop sarus cranes at Tram Chim National Park for the period 2022 - 2032. According to the project, within 10 years (period 2022 - 2032),

Implementing the AI/IoT Application Project in environmental management at Tram Chim National Park

there will be raised and released 100 cranes with a targer of minimum of 50 survivors. The released sarus cranes can reproduce on their own, survive in the wild and live year-round in Tram Chim National Park. Dong Thap province aims to receive about 30 of 6-month-old cranes from Thailand in the period 2022 - 2028 to raise, care for and release into the natural environment. The ecosystem of Tram Chim National Park will also be restored through reasonable water regulation and application of appropriate research measures, to serve the habitat of sarus cranes.

IMPLEMENTING THE AI/IOT APPLICATION PROJECT IN ENVIRONMENTAL MANAGEMENT

The return of the sarus crane took place after Tram Chim National Park implemented the AI/IoT Application Project in environmental management and received funding from the Australian Government's Aus4Innovation program. The project brings together leading experts in artificial intelligence (AI, machine learning (ML), Internet of Things (IoT), environmental technology and biological conservation from the University of Wollongong (Australia) and Polytechnic College - Ho Chi Minh City National University. Other partners of the Project include Microsoft, Tram Chim National Park and Dong Thap province.

The project uses many types of IoT devices (unmanned boats, cameras and sensors to measure turbidity, water level, temperature, CO_2, humidity) to be able to continuously and regularly survey large areas in the Tram Chim National Park. AI/ML technologies will be leveraged to process, analyze, and classify large amounts of data into indicators that provide real-time insights into the health of the Park's ecosystem (plants, animals and water). The project has built an end-to-end solution leveraging AI technology to transform the environmental management of Tram Chim National Park. The system's architecture at all levels is shown:

IoT data collection includes IoT devices (such as drones, cameras, and water sensors) that will collect data (e.g. images of animals, plants, water levels, turbidity, temperature, CO_2 and other parameters) in all areas of the Tram Chim ecosystem. Data will be continuously collected, stored in the cloud and processed in real time to provide updates on the status of the Park's ecosystem.

AI/ML data processing and classification includes a series of image processing and AI/Machine Learning algorithms and models that automatically process and analyze data to generate various insights, such as counting numbers of individuals and species animal, classify plants and identify them in different states, and determine water levels in different areas of the park.

▲ *Installing an air quality monitoring station at Tram Chim National Park*

▲ *Birds are automatically identified by the AI Camera system*

The digital AI-powered dashboard is easily accessible to various park stakeholders (such as rangers, managers and researchers) through conventional computing devices (such as personal computers, mobile phones or tablets) to support decision making. The digital dashboard will also provide a clear demonstration of how management interventions impact key indicators of the park's ecosystem health. Additionally, the console will be able to issue warning messages to users/ administrators in dangerous situations such as fire, low water levels or high salinity.

Currently, the Project is in the testing process of equipment such as 5 air quality monitoring stations, 5 water quality monitoring stations and 5 AI camera stations. In particular, cameras are equipped with identification technology to analyze, classify and evaluate plant and animal populations, especially precious birds. These are long-range wireless communication devices, so the distance between each device can be up to 10 km. The installation of equipment ensures conditions such as not destroying the natural scenery and not disturbing creatures located at the beginning or end of the water source. In addition, the structure of a monitoring station includes: solar cells, cameras, a sensor system to measure indicators and a central processor to control the sensors. Monitoring these parameters helps managers capture important indicators such as dryness, humidity, water quality, as well as fire warning signs for grasslands. These systems are designed, arranged and installed in different areas of the National Park.

After successful testing of the devices, the National Park Management Board will be provided with detailed real-time information on the health of the Park's ecosystem such as animals, plants, water, bird species identification, detecting forest fire...; thereby helping managers have more support tools to improve the quality of habitat of precious bird species. In addition, the National Park is equipped with a regular water quality monitoring system to promptly report environmental data to Provincial Leaders and Park Management Board such as: Flycams, cameras and sensors to measure turbidity and water level, temperature, CO_2, humidity to be able to conduct regular and continuous surveys over a large area in Tram Chim National Park's managers have access via personal computers, mobile phones, tablets... to support management and decision-making appropriate to water levels, weed growth and wildlife. Although Tram Chim National Park's staffs have been instructed to operate it, this is a new, high-tech model and National Park's staffs are still confused while operating or the equipment has software errors that are difficult to handle; Maintenance work must be performed annually to properly manage the equipment. The project is the first system of its kind in Vietnam to promote the sustainable, more comprehensive development of Tram Chim National Park and its wetland ecosystem, thereby improving animal health and people in the local area.

The restoration and development of sarus cranes in Tram Chim National Park brings many important meanings in the cultural and spiritual life of people in the Dong Thap Muoi region. The success of the Project along with the implementation of the AI/IoT Application Project in environmental management also makes an important contribution to preserving the sarus crane flock of the lower Mekong River region, which is currently facing with the risk of extinction in particular and in biodiversity conservation in general. This will demonstrate Vietnam's commitment and sense of responsibility when participating in international treaties ▪

NGUYỄN HOÀNG MINH HẢI – NGUYỄN HẰNG

Protecting the Hon Yen coral reef population

Hon Yen is in Phu Yen province, on the southern coast of Viet Nam. The island is famous for its beauty. The protection, conservation and development of Hon Yen coral reef (An Hoa Hai commune, Tuy An district) has received attention from the province and domestic and foreign environmental protection organizations, so the marine ecosystem in this area has many developments. Phu Yen is keeping investing and proposing the establishment of Hon Yen wetland conservation area.

THE PROSPEROUS, DIVERSE, VALUABLE MARINE ECOSYSTEM

Hon Yen complex area has many outstanding features in geology, geomorphology, flora and fauna, creating a prosperous, diverse, valuable marine ecosystem in culture, history and potential for developing coastal tourism. This place has been recognized by the Ministry of Culture, Sports and Tourism as a National Scenic Relic since 2018.

Hon Yen coral reef is located in a cluster of coral reefs from An Hoa Hai commune to An Chan commune (Tuy An district). Hon Yen coral reef complex includes Hon Yen, Hon Dun, Ban Than, Ganh Yen, Hon Choi, Vung Choi with an area of about 30.2 hectares. In this area, soft coral groups dominate. Research results on coral reefs in this area have recorded 22 species belonging to 7 families. Seagrass plants are recorded with 3 species and seaweed with 7 species. Animals have been recorded with sea stars such as Culcita novaeguineae, Echinasteridae family starfish, Acanthasterplanci crown-of-thorns starfish; sea cucumbers, sea anemones, crinoids, sea urchins, bivalves, molluscs, crustaceans... Skeletal animals are mainly reef fishes (nearly 60 species belonging to 23 families). Some fish species that are easy to see at Hon Yen at water levels of 1-4m.

Recently, experts and scientists from the Vietnam - Russia Tropical Center at the request of the provincial People's Committee have conducted a preliminary survey of coral reefs at some places capable of developing marine ecotourism. 3 points selected include: Hon Lao Mai Nha, Hon Yen (Tuy An district) and Hon Nua sea area (Dong Hoa district).

The initial results show that the coral reefs here are relatively diverse in types, beautiful andmulti-valued, including tourism development. The current situation also showsthat the coral reefs here have been destroyed due to natural factors (seastorms break), but mostly caused by negative impacts from people (environmental pollution, exploitation of coral, trampling, hunting seafood...), in which the most serious is the coral reefs of Hon Yen area.

The local community in Hon Yen is exploring new ways for economic development and generating higher income. They have established four groups of agriculture, service, tradition, and conservation. The agriculture group consists of households and individuals who work on safe vegetables, fruit gardens, and paddy rice. The service group consists of households and individuals who work on bird nests, noodle making, food catering/restaurant, and homestay. The tradition group consists of those making fish nets, fish sauce, fishing, and aquaculture. The conservation group is responsible for coral reef conservation, ensuring tourists do not step on coral reefs, and patrolling to prevent night fishing in the coral reef. Four groups with different objectives but have one joint goal of ensuring sustainable livelihoods while preserving Hon Yen's beauty. Local people want their daily activities to contribute towards protecting and conserving the island.

Moreover, the profession of net-making plays a role in promoting a circular economy. By showcasing the principles of reduce – reuse - recycle, the net-makers contribute to a sustainable and environmentally friendly approach. This not only reduces waste but also highlights the importance of utilizing available resources responsibly. They involved in this profession which play a valuable role in showcasing the rich heritage, promoting sustainable practices, and offering unique experiences to visitors. Their commitment to preserving traditional craftsmanship and embracing the principles of circular economy demonstrates the potential for traditional industries to adapt and thrive in a changing world.

In particular, special attention is paid to coral reefs in Hon Yen area, because this is a national landscape that needs to be preserved under the Heritage Law. Moreover, this coral reef is suffering a lot of negative impacts from people, even tourists visiting and taking photos can trampled on corals, because when the tide comes out, this coral reef is exposed right below their foots

JOINING HANDS TO CONSERVE HON YEN WETLANDS, CORALS

To protect and conserve Hon Yen, money is needed to fund such activities as awareness raising, patrolling, and coral planting. It is still a long way toward an independent and sustainable financing source for coral reef conservation in the island. Financial management training will be provided for the local communities to sustain their economic-conservation model. The local communities will better protect and conserve Hon Yen with all their heart and souls and in return, the beautiful island will cherish their life.

Local communities in An Hoa Commune, Tuy An District of the southern province of Phú Yên have been making changes to conserve the Hon Yen wetlands while still improving their livelihoods through sustainable economic development. People are empowered to manage and protect the environment, and protect the Hon Yen coral ecosystem.

From August 2020 to September 2022, the Global Environment Fund-Small Grants Programme in Vietnam under the United Nations Development Program (GEF SGP/UNDP) supported Phu Yen province in strengthening the capacity of local communities to conserve the Hon Yen wetlands. The project's total funding is nearly 3.2 billion VND, of which nearly 1.1 billion VND came from GEF SGP/UNDP, 900 million VND from the Vietnam - Russia Tropical Centre under the Ministry of National Defence and about 1.2 billion VND from Phu Yen Province's own budget. The project's goal is to improve community awareness and capacity in managing and exploiting marine resources and protecting ecosystems.

▲ *Coral reefs are quite rich in types and beautiful in Hon Yen Area*

According to the People's Committee of An Hoa Hai commune, in order to protect the Hon Yen coral reef population, in addition to the provincial and district authorities, the locality has established a cooperative group to manage, protect and preserve coral reefs, and organize a community tour to contribute to creating sustainable livelihoods for local people.

The project of Strengthening Community Capacity in Conservation of Hon Yen Coral Reef Population initially formed a policy and mechanism framework, providing capacity for the local community to protect local natural resources. The project has assigned the right to manage and protect Hon Yen coral and develop regulations to coordinate the implementation of a co-management mechanism between the cooperative group and relevant organizations and individuals.

In April 2023, the Provincial People's Committee issued a decision regulating the management, protection and conservation of Hon Yen coral reef. The plan to protect and preserve the Hon Yen coral ecosystem has established 4 functional areas. Accordingly, the core area (A0) has a reef area of nearly 17.7 hectares, currently has a coral reef foundation, seagrass beds, and distributed seaweed. This area is strictly protected to minimize impact on the coral ecosystem. The buffer zone (B1) with an area of about 22.5 hectares, is established as a subdivision linking tourism and geological research, a potential area capable of developing ecotourism. The buffer zone (B2) has an area of about 20 hectares, a subdivision for lobster farming and nursery development to ensure the main source of income for the community living here. In the long term, it will develop towards a tourism service model and a scientific tour model. Buffer zone (B3) with an area of about 8.35 hectares, the fisheries logistics service sub-zone is a concentrated area for anchoring fishing boats and fishing logistics services during stable weather times of the year. Limiting the concentration of too many boats during the rainy season and high tides ▪

NGUYỄN THẮNG

Quang Ninh improves marine environment for sustainable development

With the advantages of natural landscapes and beautiful waters, sea and island tourism has long been a tourism form of strength for Quang Ninh. In addition to Ha Long bay, the names such as Co To, Quan Lan, Minh Chau, and Tra Co have become more attractive, affirming the province's important position on the sea and island tourism map of the country.

EXPLOITING THE SEA AND ISLAND POTENTIAL

The tourism sector in the northern coastal province of Quang Ninh has been growing at a fast pace in recent years, establishing its important role in the province's economy and moving towards sustainability.

Quang Ninh is endowed with natural advantages for sea and island tourism. It is home to the Ha Long and Bai Tu Long bays, the Ha Long Bay National Park and some islands, the best known of which is Co To and Van Don. In particular, Ha Long bay has been twice recognized as a World Natural Heritage site by the UNESCO. The Heritage site has become a magnet drawing visitors to Quang Ninh. Quang Ninh has been expanded the space for sea and island tourism farther from Ha Long bay towards islands such as Co To, Van Don and Hai Ha. Quang Ninh is primed to develop tourism infrastructure to welcome millions of tourists every year. The province has set an objective to increase sea tourism's share to 75-80 per cent of its total number of visitors by 2030 or 28.5 million, of which 8 million would be foreign visitors.

In order to realize the said objective, Quang Ninh placed great importance on building a model of sustainable tourism and improving the quality of services across the board for visitors. Quang Ninh had made significant investments in developing and upgrading its infrastructure networks to connect all tourism hubs to the major road networks in the Red River Delta. The province had been working with businesses and developers to set up far-reaching systems of malls, supermarkets, convenience stores, vending machines and traditional markets, all situated in close proximity to local tourist attractions. In the coming years, more quality products and services were to become available to visitors, especially the high-end segment of the market. The province has paid attention to the creation of new tourist products and improvement of service quality. A diverse range of sea and island tours are now available for visitors, from relaxation to entertainment and adventure.

Quang Ninh has traditionally played an important part in Vietnam northern region logistics network. The province is home to numerous seaports, some are among the most modern ports in the region. In addition, the province has set a course to expand its aquaculture production with a focus on improving connectivity with road infrastructure in the region. The province aims to increase seafood production to 225,000 tones and export value to half a billion dollars by the end of 2030.

With an eye on sustainable development, measures have been taken to raise awareness among fishing communities as well as the implementation of stricter environmental laws, aiming to protect and preserve the ocean's natural resources. Various projects have also received the go-ahead to set up logistic centres, food processing hubs and repair shops for fishing vessels as the province looks to improve efficiency and create added value for seafood products.

Equipped with a strategic vision for developing the sea-based economy, the province in 2014 approved an Overall Plan for tourism development to 2020 with a vision to 2030. Under the scheme, the sea

▲ *The tourism sector in the northern coastal province of Quang Ninh has been growing at a fast pace in recent years*

space in Quang Ninh is divided into five zones, which are the strictly preserved Ha Long bay, the conservation area in Bai Tu Long National Park, the tourism zone, the zone with restricted development to serve national defense and security, and the zone with no development. Each zone, with their specific characteristics, has close links with each other to support the development of sea-based tourism and economy while ensuring national defense and security and serving the province's sustainable development.

BECOME A STRONG MARINE-BASED ECONOMIC HUB

Tourism and sea economy continue to play large parts in the development strategy for the Northern coastal province of Quang Ninh. The northern province of Quang Ninh has outlined key measures to develop its marine-based and coastal economy, with a focus on eco-friendly tourism, maritime services, and coastal industry. Quang Ninh is on the way to becoming one of the country's strong marine-based economic hubs, serving as a gateway and driving force of development in the northern key economic region with a network of deep-water seaports. Key localities such as Ha Long, Cam Pha, Mong Cai, Quang Yen, Van Don, Co To and Hai Ha have been connected to marine-based economic sectors and become national tourist destinations linked with major international tourism hubs in the region and the world via waterways.

Regarding maritime tourism and services, Quang Ninh is striving to become an international tourism hub with modern and concerted infrastructure, possess diversified and quality tourism products, a strong trademark imbued with the national cultural identity, and high competitiveness compared to countries in the region and the world, be a driving force of rapid and sustainable socio-economic development, and guarantee national defense and security.

The province will enhance investment in building tourism and trade infrastructure in coastal and island areas, making it easier for economic sectors to develop quality sea-island ecological tourism, community-based tourism, and international trade hubs. Ha Long will be developed into a modern and civilized marine tourist city while Van Don - Co To will become a high-quality sea and island tourism centre and a world-class regional entertainment hub by 2030.

The province will upgrade its fishing ports and wharves, offer fisheries logistics services in Co To and Van Don districts, and establish three key fishing centres in combination with aquaculture and key fishing grounds in localities and two seafood trade centres in Ha Long. It will also develop logistics infrastructure to make it a sector providing high added value in tandem with promoting foreign trade.

Regarding coastal industry and new-model economic sectors, Quang Ninh has prioritized eco-friendly high-tech industrial sectors, manufacturing and processing such as shipbuilding and repair, and cruise tourism, while boosting connectivity between shipbuilding and support industries and encouraging foreign investment in support industries for shipbuilding.

Quang Ninh will develop the processing of aquatic products by using modern technology and improving efficiency, with a focus on food safety, to meet the quality standards demanded by major markets globally. Quang Ninh will also make use of the achievements of Industry 4.0 to switch from the export of raw materials to deep processing, thus creating added value and saving marine resources. At the same time, it will study several industries in service of the marine-based economy, seaport-logistics services, the new materials industry, tourism, and entertainment.

The province will also pay attention to several marine-based economic sectors based on advantages in marine resources and biodiversity. The province has set a goal to have modern industry and service sectors and become one of the region's comprehensive and dynamic development hubs by 2025.

Quang Ninh has recently implemented many solutions to protect the marine environment and marine resources. Thanks to these actions, Quang Ninh's fishing grounds, especially in coastal areas, have witnessed the reappearance of schools of fish and shrimp while some estuary areas have welcomed herds of rare dolphins, whales, and sea turtles.

With enormous efforts in protecting the marine environment and resources, Quang Ninh's waters have become clean, beautiful, and rich in resources. This is an important condition for Quang Ninh to develop a sustainable marine economy, including marine exploitation, aquaculture, and tourism activities. Quang Ninh aims to develop a blue ocean economy, sustainably use marine resources for economic growth, improve people's livelihoods, and ensure the health of marine ecosystems rather than developing the marine economy at any cost ▪

TRẦN TÂN

Preserving biodiversity in the Van Long Nature Reserve

Van Long Wetland Nature Reserve in Gia Vien district is one of the largest wetland areas in the Red River Delta and the 9th Ramsar of Vietnam, with rich natural resources and unique ecosystem. Apart from exploiting tourism potential, in the past few years, Gia Vien district has also paid due attention to preserving biodiversity in the Van Long Nature Reserve.

RICH NATURAL RESOURCES AND UNIQUE ECOSYSTEM

The Van Long Nature Reserve covers a total area of 2,700 hectares, spanning over seven communes of Gia Vien district. It boasts rich biodiversity resources and an attractive landscape with limestone mountains, rivers and caves.

Van Long Wetland Nature Reserve is one of the few intact lowland inland wetlands remaining in the Red River Delta, and also the largest wetland nature reserve in the northern region. It is home to two ecosystems, the wetland environment and the limestone ecosystem.

According to the latest survey in 2020, Van Long is home to 722 species of flora, 15 of which are listed in the Red book of Vietnam. It has 39 species of animals; 100 species of birds, 38 species of reptiles, 43 species of fish and 132 species of insects. In particular, Van Long is home to a large population of Delacour's langurs.

Van Long holds two national natural records - the nature reserve with the biggest group of Delacour's langurs, a critically endangered species at home and abroad, and the area with the "largest picture of nature". These are great potential and advantages for Van Long to develop tourism in combination with ecosystem preservation.

Thanks to the cooperation of local authorities and people, the biodiversity preservation has been carried out effectively, thereby wild animals live safely in the nature. In 2000, there were only 40 Delacour's langurs living in the nature, to date, the number has risen to over 200, and they live in separate groups.

The reality shows that preserving the nature landscape will bring about dual results: protecting the environment and becoming an important resource to develop tourism and services.

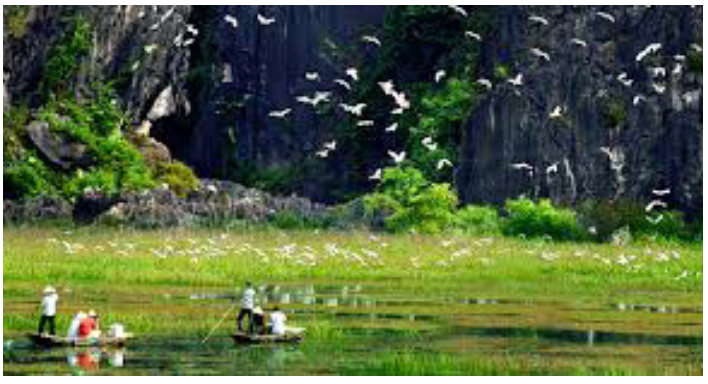
Gia Vien has implemented numerous measures to fully exploit biodiversity in a bid to develop tourism in a green and sustainable way, thus fulfilling the task of turning tourism into a spearhead economic sector.

With diverse natural resources and rich ecosystems, Van Long Wetland Nature Reserve in Gia Vien district, the northern province of Ninh Binh, has many advantages and potential to develop a service-based economy, effectively contributing to local socio-economic development.

Protecting the landscape, environment and biodiversity of Van Long plays an important role in the district's tourism and socio-economic development, helping to create jobs and improve incomes for the locals. The authorities and locals at the nature reserve have made efforts to implement measures to protect its environment and natural beauty. In order to promote the locality's advantages, the province needs to strengthen education, research and development of specific tourism products associated with biodiversity conservation and environmental protection.

Van Long Wetland Nature Reserve receives a large number of visitors every year. Between May and September is the best season to explore the reserve. The nature reserve is among various attractions in Ninh

▲ *Van Long Wetland Nature Reserve in Gia Vien district is one of the largest wetland areas in the Red River Delta and the 9th Ramsar of Vietnam*



▲ *Van Long Wetland Nature Reserve receives a large number of visitors every year*

Binh province, which is blessed by nature with a wide range of beautiful natural landscapes and ecosystems. Other sites in Ninh Binh that have become familiar to tourists including Tam Coc - Bich Dong, Cuc Phuong National Park, and particularly the Trang An Landscape Complex. The Trang An complex was recognized by UNESCO as a World Cultural and Natural Heritage Site in 2014 - the first in Vietnam and Southeast Asia to receive the honors.

CONSERVATION AND SUSTAINABLE DEVELOPMENT

The Government recognition and local involvement have made species conservation a success and an ideal tourist attraction. Van Long Nature Reserve has been one of the most successful examples in Vietnam of a unique conservation model between community-based tourism development and species and habitat conservation. The Van Long Nature Reserve Management Board and local authorities need to continue to work together, share benefits from tourism activities and reinvest in protection efforts in order to have better management of the wetland and karst ecosystem and its unique biodiversity.

The successful recovery of Delacour's langur population in Van Long Nature Reserve is a great story in itself. It has inspired other Protected Areas, as it provides an effective Protected Areas-based conservation approach. With good management and protection, as well as better law enforcement, introduced by the establishment of the Nature Reserve, the karst and wetland ecosystems in the area were well maintained and rehabilitated. In the last 20 years, the limestone forest cover has rapidly increased by up to 30%. While habitats improved, the number of wintering waterbirds has significantly increased, making Van Long an interesting birdwatching site that is attracting significant bird-watchers every year. Local communities have new livelihoods from eco-tourism. Being aware of the benefits from conservation of the Nature Reserve, many of the local people now actively participate in conservation work, such as patrolling and environmental education activities.

Van Long is thriving both in terms of conservation and ecotourism development. With the close cooperation between the local communities and the new official management authorities, Van Long has wiped out the threats from forest fires, hunting, fire-wood exploitation. Local people are directly involved in the tourism operations and many families are earning much higher incomes from farming. Even some of the external tourism ventures still hire local people and use local services. Training for tourism has greatly benefited the local people. The success of biodiversity conservation has been a phenomenal, especially in the context of a national decline in most areas and species. Van Long is developing a new conservation management plan for further restoration and possible expansion of the reserve into the forested hills further to the North. Van Long Nature Reserve is highly valued by the Provincial level as well as the Central level. Van Long as also used for the International Wetland Day celebration ceremony by the Ministry of Environment. The local communities are proud of the importance of Van Long.

Management Board surveys have shown that the local community have an increased appreciation and value for Van Long, and they care much more for the protection activities carried out by the reserve and community staff. As such, the management objectives are achieved, and tourism is flourishing. The core area of biodiversity conservation in Van Long is proving very effective in conserving biodiversity. This is demonstrated through the increasing number of water bird colonies in the area and the increase in number of groups and population of the Delacour's langur.

It is therefore crucial to have funding from the Government and outside to support conservation activities. There is a need for research activities, communications and education activities, community development, but there is no budget for any activities rather ran bare functions of patrols and law enforcement. There is a huge need to support local communities in improving livelihoods. The support from the Government is important to create an equal benefit sharing mechanism. Community development projects are needed to support local people improving their incomes. These should be funded in part by revenue from tourism ▪

CHÂU LONG

환경부
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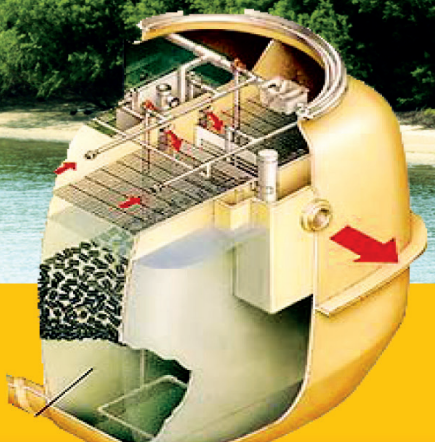

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