

Assessment of pollution load from industrial activities of Nghi Son Economic Zone (Thanh Hoa province)

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Received: 22 April 2020; Accepted: 30 July 2020

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Abstract

Thanh Hoa coastal waters have received a large amount of waste from industrial activities of Nghi Son Economic Zone such as thermal power, vegetable oil production, wood processing, steel rolling and petroleum refinery. Employing environmental rapid assessment method, the discharged industrial wastewater from Nghi Son Economic Zone was calculated. The pollution load includes organic matter (13 thousand tons), total nitrogen - TN (27.4 thousand tons), total phosphorous - TP (967.8 tons), total suspended solid - TSS (12.3 thousand tons). In addition, wastewater also contained phenol, oil and grease, cyanide, sulfites, heavy metals (Fe, Zn, Cr). If this wastewater is not treated, the amount of pollutant discharged to Thanh Hoa coastal area will be much greater and impact on sensitive ecosystems.

Keywords: Pollution load, pollutants, industry, economic zone, Nghi Son.

INTRODUCTION

Nghi Son Economic Zone (EZ) was established in 2006 and expanded in 2018 by decision No. 1669/QĐ-TTg of the Prime Minister. Accordingly, Nghi Son EZ has a total area of 106,000 ha, including 66,497.57 ha of land and islands, and 39,502.43 ha of water surface. Playing a significant role for socio-economic development of Thanh Hoa province and the whole country, Nghi Son EZ, as a multi-sector integrated economic zone, is composed of industrial sectors such as petrochemical, steel rolling, ship building and repairing, electric production, construction material production, consumer goods production and export processing,... associated with effectively exploiting Nghi Son seaport. The expected outcomes of the EZ are products of high quality and competitiveness worldwide.

Accompanying with industrial activities, Nghi Son EZ every year generates tens of million cubic meters of wastewater from activities such as steel rolling, wood processing, seafood processing, petrochemical, cement production, beer production and thermal power generation. Besides common pollutants as organic matter and nutrients, the wastewater also contains other toxic chemicals including phenol, cyanide, chromium, zinc, chloride,... Water pollution and ecosystem damage will be at risk if wastewater is not thoroughly treated.

Assessment of pollution load from land-based source in general and industrial source in particular has been much paid attention over the world. For example, Asmah and Biney (2001) carried out assessment for the coastal zone of the Accra-Tema metropolitan area [1]; Nader et al., (2014) assessed pollution load in Karun River Drainage Basin, Southwest of Iran [2]; Zhao et al., (2015) studied land-based pollution for Quanzhou bay [3]; and nutrient pollutant loading along Mediterranean rivers was investigated by Sania (2020) [4]. These studies aim at preventing and controlling land-based waste sources. In Vietnam, pollution load from land-based source has been mentioned in a number of articles [5–8] which show that coastal areas will receive daily a huge amount of waste if they are not controlled thoroughly.

Marine environment and ecosystems may be at risk of pollution. However, pollution load is not well concerned in Nghi Son EZ. Presently, there is not any study related to pollution load from land-based sources in the area. This study aims at calculating the pollutant discharge load generated by industrial activities in Nghi Son EZ in cases of treated and untreated wastewater. The study results will contribute to environmental management with an overall picture of pollutant discharged from industrial activities in the region and will provide better control solutions to waste sources.

MATERIALS AND METHODS

Study area

Nghi Son EZ is located in the south of Thanh Hoa province, 50 km from Thanh Hoa city. It connects to East Sea in the east, borders the Quynh Luu district (Nghe An province) in the south, and borders Nhu Thanh district in the west and Nguyen Binh, Binh Minh communes (Tinh Gia district) in the north. The whole economic zone covers 12 communes and wards of Nghi Son town, namely Xuan Lam, Tinh Hai, Hai Yen, Mai Lam, Hai Thuong, Hai Ha, Nghi Son, Truc Lam, Truong Lam, Tung Lam, Tan Truong and Hai Binh. At present, Nghi Son EZ has completed infrastructure construction, including transportation system, electricity, water supply and telecommunication services. Other facilities such as hotel services, commerce, health center,... are also planned.

Up to 2017–2018 in Nghi Son EZ, there were 148 investment projects dealing the production of bricks, cement, fresh concrete, construction materials, port construction, wood processing, steel rolling, petroleum services, mechanics, ship repair, water supply, infrastructure construction, waste treatment, thermal power plants, beer production, eco-tourism, commercial services, restaurants, hotels, hospitals, schools,... When companies are in operation, a huge amount of waste will be generated and discharged to coastal waters in Thanh Hoa province.

Nghi Son EZ still has no centralized wastewater treatment system. Thus, the enterprises invest their own local wastewater

treatment facilities, then discharge treated wastewater to common sewage connecting to Lach Bang and Tuan Chung rivers. Therefore, it is very vital to control wastewater from the enterprises in the EZ.

Materials

To assess pollution load generated from the companies in the EZ, data and documents from annual reports of some related companies such as Tuong An Vegetable Oil Joint Stock Company (2016), Cong Thanh Cement Plant (2016), Hoa Phat Steel Factory (2017) and EIA report of Hiep Hoa Tunnel Brick were used. For cement factories in the area, due to lack of information on concentration of contaminants, EIA reports and waste monitoring reports of

Hai Phong Cement Factory (1997) and Chinfon Cement Factory (2018) were referred.

Methods

Method for estimation of domestic wastewater load

Domestic wastewater load in individual company is calculated by the following formula:

$$Q_{dc} = P \times Q_i \times 10^{-3} \text{ [9]}$$

Where: Q_{dc} : Domestic wastewater load of the factory or company (ton/year); P : Total people in the the factory or company (person); Q_i : Waste load factor of pollutant i in domestic wastewater (kg/person/year) (table 1).

Table 1. Waste load factor in domestic wastewater [9]

No.	Pollutants	Waste load factor (kg/person/year)	Bio-treatment efficiency (%)
1	COD	$1.6 \times BOD_5$	30–60
2	BOD ₅	18.1	50–80
3	T-N	3.3	20–50
4	T-P	0.93	10–30
5	TSS	39.2	70–95
6	NO ₃ + NO ₂ *	0.33	20–50
7	NH ₄ *	0.792	20–50
8	PO ₄ *	0.418	10–30
9	V wastewater	55 m ³ /person/year	

Notes: (*): After San Diego - McGlone et al., (2000) [10]; COD: Chemical Oxygen Demand; BOD: Biochemical Oxygen Demand; T-N: Total Nitrogen; T-P: Total Phosphorous; TSS: Total Suspended Solid.

Highest bio-treatment efficiency of domestic wastewater in companies (table 1) is taken for calculation.

Method for estimation of production wastewater load

The production wastewater load is calculated based on the output of the product multiplied by the waste load factor per one product unit generated. The waste load factor of some typical industries is presented in tables 2–5.

Table 2. Waste load factor of some industries

Type of industries	Waste load factor (kg/ton of product/year)							
	COD	BOD ₅	TSS	T-N	T-P	NO ₃ ⁻ + NO ₂ ^{-*}	NH ₄ ⁺ *	PO ₄ ^{3-*}
Fish processing	19.0	7.3	9.4	0.7	0.31	0.01	0.27	0.16
Frozen shrimp	312.0	120	220	10.0	5.04	0.10	3.80	2.52
Cooking oil	64.7	24.9	24.6	12.5	1.05	0.13	4.75	0.53
Grain mill product (rice)	4.7	1.8	0.07	0.9	0.08	0.01	0.34	0.04
Sugar production	7.5	2.9	6.3	1.5	0.12	0.02	0.57	0.06
Beer production (1000 l)	27.3	10.5	3.9	5.3	0.44	0.05	2.01	0.22
Paper manufacture	14.3	5.5	10.5	2.8	0.23	0.03	1.06	0.12
Wood processing	32.5	12.5	20	6.3	0.53	0.06	2.39	0.27
Treatment efficiency of activated mud**	0.80–0.85	0.80–0.95	0.80–0.90	0.15–0.50	0.10–0.25	0.08–0.15	0.08–0.15	0.10–0.25

Source: Economopous (1993) [9]; (*): Calculated after San Diego-McGlone et al., (2000) [10]; (**): Tran Van Nhan, Ngo Thi Nga (2002) [11].

Table 3. Waste load factor of steel rolling production [9]

No.	Kind of furnace	Waste load factor (kg, m ³ /ton of product)					
		Waste volume	BOD ₅	TSS	Total N	Total P	Others
1	Blast furnace	12.3		29.3	0.27		Phenol - 0.01 F - 0.023 CN - 0.039
2	Basic oxygen furnace	3		0.231			Oil - 3.92 Fe - 24.99 SO ₄ - 22.1 Cl - 24.8 Zn - 0.007 Cr - 0.015
3	Electric arc furnace	69.2	2.2	37.56		0.02	

Table 4. Waste load factor of petroleum refineries [9]

Capacity	Waste volume	Waste load factor (kg, m ³ /1,000 m ³ of crude)						
		BOD ₅	TSS	Total N	Oil	Phenol	Sulfide (S ²⁻)	Cr
1,000 m ³ crude	484	3.4	11.7	1.2	8.3	0.034	0.054	0.007

Table 5. Waste load factor from coke burning (kg/ton of product) [9]

	BOD	N-T	Phenol	CN-	SCN-	V of wastewater (m ³ /ton of product)
Untreated	3.9	3.5	0.28	0.61	2.1	14.7
Old plant	0.7	3.5	0.28	0.03	0.13	9.9
Base level treatment	0.3	3.5	0.04	0.015	0.06	9.9
Biological treatment	0.3	3.5	0.07	0.02	0.08	1.6

Treatment efficiency of production wastewater (table 2) using activated mud is considered the main method in all factories in which the highest treatment efficiency was chosen. For industries that have no data on waste load factor, it can be calculated relatively based on the information given in similar environmental impact assessment reports or referencing pollutant concentration in the same type of wastewater.

RESULTS AND DISCUSSION

Pollution load from cement industry

In the Nghi Son EZ, there are two cement factories, Cong Thanh Cement and Nghi Son Cement. According to the 2016 annual report of Cong Thanh Cement Plant, current capacity of the plant is about 5 million tons of cement and 750,000 tons of clinker per year, creating jobs for 750 employees and workers. In future, the capacity will be increased more than 3 million tons of clinker per year (equivalent to 4 million tons of cement per year). For the Nghi Son Cement, the average output is about 4.3 million tons/year, and there are around 1,300

workers. In future, Nghi Son Cement Phase 2 has a capacity of 2.15 million tons/year, therefore total capacity of the Nghi Son Cement will be 6.45 million tons/year.

Due to lack of information related to volume of wastewater and concentration of pollutants in wastewater from the two plants, those data of Chinfon and Hai Phong Cement Plants were referred, such as 0.21 m³ wastewater/ton of cement, concentrations of pollutants in cement wastewater before treatment from the EIA report of Hai Phong Cement Plant (1997) and after treatment from the 2018 monitoring results of the Chinfon Hai Phong Cement Plant. With the capacity of Cong Thanh and Nghi Son Cement Plants (Phase 1 (at current) and Phase 2 (in future)), the volume of wastewater is about 3.4 million m³/year and the pollution load is calculated (table 6).

The production wastewater of cement also contains a large number of suspended solids and dissolved solids. If it is not treated, changes of water balance in coastal waterbody will affect the organism growth and development [12].

Table 6. Pollution load from Cong Thanh and Nghi Son Cement Plants - Phases 1 and 2 (ton/year)

Pollutants	Before treatment					After treatment				
	Cong Thanh		Nghi Son		Total	Cong Thanh		Nghi Son		Total
	D.W	P.W	D.W	P.W		D.W	P.W	D.W	P.W	
COD	36.9	255.9	59.5	169.3	521.7	14.8	38.4	23.8	25.4	102.4
BOD ₅	23.1	65.5	37.2	43.3	169.1	4.6	3.3	7.4	2.2	17.5
T-N	4.2	24.8	6.8	16.4	52.2	2.1	12.4	3.4	8.2	26.1
T-P	1.2	1.4	1.9	0.9	5.5	0.8	1.1	1.3	0.7	4.0
NO ₃ +NO ₂	0.0	0.1	0.1	0.1	0.4	0.02	0.1	0.0	0.1	0.3
NH ₄ ⁺	1.0	3.5	1.6	2.6	8.8	0.5	3.0	0.8	2.2	6.5
PO ₄ ³⁻	0.5	0.4	0.9	0.3	2.1	0.4	0.3	0.6	0.2	1.5
TSS	50.0	2,047.5	80.6	1,354.5	3,532.5	2.5	204.8	4.0	135.5	346.7
TDS		1,535.6	0.0	1,015.9	2,551.5		743.8	0.0	556.2	1,300.1
Oil and grease		1.1	0.0	0.7	1.9		1.7	0.0	1.3	3.0

Notes: D.W: Domestic wastewater; P.W: Production wastewater.

Pollution load from beer and vegetable oil production industries

Nghi Son Beer Factory has been in operation since 2010 with a capacity of 30 million liters per year and about 500 workers. Vegetable Oil Company started production from 2016 with a capacity of 1,500 tons of oil per day and about

300–500 persons. The pollutant discharge load of these two plants is calculated in table 7.

Table 7 shows that beer and vegetable oil factories generate a huge amount of organic matter and grease that may cause the lack of dissolved oxygen in water body if the large amount of wastewater is discharged [13].

Table 7. Pollution load from beer and vegetable oil production industries in Nghi Son EZ (ton/year)

Pollutant	Before treatment					After treatment				
	Beer		Vegetable oil		Total	Beer		Vegetable oil		Total
	D.W	P.W	D.W	P.W		D.W	P.W	D.W	P.W	
COD	14.5	819.0	11.6	35,423.3	36268.3	5.8	122.9	4.6	5313.5	5,446.8
BOD ₅	9.1	315.0	7.2	13,632.8	13964.0	1.8	15.8	1.4	681.6	700.6
T-N	1.7	159.0	1.3	6,843.8	7005.7	0.8	79.5	0.7	3421.9	3,502.9
T-P	0.5	13.2	0.4	574.9	588.9	0.3	9.9	0.3	431.2	441.6
NO ₃ +NO ₂	0.02	1.59	0.01	68.44	70.06	0.01	1.35	0.01	58.2	59.54
NH ₄ ⁺	0.4	38.2	0.3	1,642.5	1,681.4	0.2	32.4	0.2	1,396.1	1,428.9
PO ₄ ³⁻	0.2	5.9	0.2	258.7	265.0	0.1	4.5	0.1	194.0	198.7
TSS	19.6	117.0	15.7	13,468.5	13,620.8	1.0	11.7	0.8	1,346.9	1,360.3
Oil				15,384.8	15,384.8	0.0	0.0	0.0	2,307.7	2,307.7

Notes: D.W: Domestic wastewater; P.W: Production wastewater.

Pollution load from seafood processing industry

There are about 21 seafood processing units operating in Nghi Son EZ with many items such as fish rolls, fishmeal, frozen fish; frozen shrimp, etc. The yield is over 50 thousand tons of products per year. The number of employees is over 2,000 persons. There are 4 large factories: Nghi Son Seafood Processing Factory (7,500 tons/year); Long Hai Seafood Processing Factory (16,000 tons/year); Ngoc Son Seafood

Processing Factory (22,800 tons/year); Quang Le Seafood Preliminary Processing Workshop (300 tons/year). The calculated results of pollution load of these seafood processing units are presented in table 8.

The wastewater of seafood processing industry mainly contains large amounts of organic matter which is easily treated effectively (tables 1, 2). However, most of seafood processing units are small, it is difficult for environmental protection.

Table 8. Total pollution load from seafood processing factories in Nghi Son EZ (tons/year)

Pollutants	Before treatment									After treatment								
	Nghi Son		Long Hai		Ngoc Son		Quang Le		Total	Nghi Son		Long Hai		Ngoc Son		Quang Le		Total
	D.W	P.W	D.W	P.W	D.W	P.W	D.W	P.W		D.W	P.W	D.W	P.W	D.W	P.W			
COD	9.6	142.5	20.3	304.0	29.0	433.2	2.9	5.7	947.1	3.8	21.4	8.1	45.6	11.6	65.0	1.2	0.9	157.5
BOD ₅	6.0	54.8	12.7	116.8	18.1	166.4	1.8	2.2	378.7	1.2	2.7	2.5	5.8	3.6	8.3	0.4	0.1	24.7
T-N	1.1	5.3	2.3	11.2	3.3	16.0	0.3	0.2	39.6	0.5	2.6	1.2	5.6	1.7	8.0	0.2	0.1	19.8
T-P	0.3	2.3	0.7	5.0	0.9	7.1	0.1	0.1	16.4	0.7	0.2	0.2	1.6	0.5	3.5	0.7	4.9	12.2
TSS	12.9	70.5	27.4	150.4	39.2	214.3	3.9	2.8	521.5	2.0	0.5	0.6	3.5	1.4	7.5	2.0	10.7	28.2
NO ₃ +NO ₂	0.01	0.05	0.02	0.11	0.03	0.16	0.00	0.00	0.40	0.01	0.04	0.01	0.10	0.02	0.14	0.00	0.00	0.31
NH ₄ ⁺	0.26	1.26	0.55	2.69	0.79	3.83	0.08	0.05	9.52	0.40	1.07	0.13	2.28	0.28	3.26	0.40	0.04	7.85
PO ₄ ³⁻	0.14	1.05	0.29	2.23	0.42	3.18	0.04	0.04	7.39	0.10	0.73	0.21	1.56	0.29	2.23	0.03	0.03	5.17

Notes: D.W: Domestic wastewater; P.W: Production wastewater.

Table 9. Total pollution load from wood processing factories (tons/year)

Pollutants	Before treatment									After treatment								
	Minh Long		Nghi Son		Innovgreen		Exporting wood		Total	Minh Long		Nghi Son		Innovgreen		Exporting wood		Total
	D.W	P.W	D.W	P.W	D.W	P.W	D.W	P.W		D.W	P.W	D.W	P.W	D.W	P.W	D.W	P.W	
COD	2.90	240.5	2.9	990.6	14.5	4,790.5	2.9	1,092.0	7,136.8	1.2	36.1	1.2	148.6	5.8	718.6	1.2	163.8	1,076.3
BOD ₅	1.81	92.5	1.8	381.0	9.1	1,842.5	1.8	420.0	2,750.5	0.4	4.6	0.4	19.1	1.8	92.1	0.4	21.0	139.7
T-N	0.33	46.6	0.3	192.0	1.7	928.6	0.3	211.7	1,381.6	0.2	23.3	0.2	96.0	0.8	464.3	0.2	105.8	690.8
T-P	0.09	3.9	0.1	16.2	0.5	78.1	0.1	17.8	116.8	0.7	0.4	0.1	2.9	0.1	12.1	0.3	58.6	75.2
TSS	3.92	148.0	3.9	609.6	19.6	2,948.0	3.9	672.0	4,409.0	2.0	2.0	0.2	14.8	0.2	61.0	1.0	294.8	375.9
NO ₃ +NO ₂	0.00	0.5	0.0	1.9	0.0	9.3	0.0	2.1	13.8	0.0	0.4	0.0	1.6	0.0	7.9	0.0	1.8	11.7
NH ₄ ⁺	0.08	11.2	0.1	46.1	0.4	222.9	0.1	50.8	331.6	0.4	1.3	0.0	9.5	0.0	39.2	0.2	189.4	240.1
PO ₄ ³⁻	0.04	1.8	0.0	7.3	0.2	35.2	0.0	8.0	52.5	0.0	1.3	0.0	5.5	0.1	26.4	0.0	6.0	39.4

Notes: D.W: Domestic wastewater; P.W: Production wastewater.

Pollution load from wood processing industry

Currently, there are 4 wood processing factories operating in Nghi Son EZ: Minh Long 68 Factory (capacity 8,000 m³ of timber/year); Nghi Son Factory (capacity 30,000 tons/year); Innogreen Thanh Hoa Company (capacity 85,000 m³ of plywood and pulp/year and 20,000 tons of wood chips/year); Factory for Production of Flooring, Industrial Plywood and Wood Chips (capacity 4,500 m³ of plywood/year and 30,000 tons of wood chips/year). The number of employees in this industry is about 500 persons. The pollution load of 4 factories in Nghi Son EZ is calculated in table 9.

The production wastewater of wood processing factories contains a large amount of C, N, P and TSS. Wastewater discharges are mainly from Innogreen Thanh Hoa Company (67.3%), followed by Factory for Production of Flooring, Industrial Plywood and Wood Chips (15.3%) and Nghi Son Wood Processing Factory (13.9%). Wood processing often

produces a great number of products and will locally pollute Mai Lam, Hai Binh and Truong Lam communes of Tinh Gia district if wastewater is untreated.

Pollution load from steel industry

This industry includes two large companies, namely Nghi Son Steel Rolling Mill (operated from 2019 with a capacity of 2 million tons per year, using electric arc furnace technology) and POMIDO Steel Mill (has been licensed, but not yet been operating, with a capacity of 650,000 tons per year). The number of employees at two factories is about 10,000 persons. The discharge load is calculated in table 10.

When the two companies are fully operational, a large number of heavy metals (such as iron, zinc and chromium) and suspended solids will be released into the coastal area. The volume of wastewater from Nghi Son Steel Company accounts for 75% of the wastewater from steel production in Nghi Son EZ.

Table 10. Pollution load from steel rolling industry in Nghi Son EZ (ton/year)

Pollutants	Before treatment					After treatment				
	Nghi Son		POMIDO		Total	Nghi Son		POMIDO		Total
	D.W	P.W	D.W	P.W		D.W	P.W	D.W	P.W	
COD	173.8	6,780.0	115.8	2,203.5	9,273.1	69.5	1,017.0	46.3	330.5	1,463.4
BOD ₅	108.6	4,400.0	72.4	1,430.0	6,011.0	21.7	220.0	14.5	71.5	327.7
T-N	19.8	0.0	13.2	0.0	33.0	9.9	0.0	6.6	0.0	16.5
T-P	5.6	400.0	3.7	130.0	539.3	3.9	300.0	2.6	97.5	404.0
NO ₃ + NO ₂	0.20	0.00	0.13	0.00	0.33	0.10	0.00	0.07	0.00	0.17
NH ₄ ⁺	4.8	0.0	3.2	0.0	7.9	2.4	0.0	1.6	0.0	4.0
PO ₄ ³⁻	2.5	180.0	1.7	58.5	242.7	1.8	135.0	1.2	43.9	181.8
TSS	10.8	75,120.0	10.8	24,414.0	99,555.6	0.5	7,512.0	0.5	2,441.4	9,954.5
Oil		7,840.0		2,548.0	10,388.0		150.0		48.8	198.8
Fe		49,980.0		16,243.5	66,223.5		14,994.0		4,873.1	19,867.1
SO ₄		44,200.0		14,365.0	58,565.0		13,260.0		4,309.5	17,569.5
Cl-		49,600.0		16,120.0	65,720.0		14,880.0		4,836.0	19,716.0
Zn		14.0		4.6	18.6		4.2		1.4	5.6
Cr		30.0		9.8	39.8		9.0		2.9	11.9

Notes: D.W: Domestic wastewater; P.W: Production wastewater.

Pollution load from thermal power industry

Nghi Son 1 Thermal Power Plant is currently operated with a capacity of 600 MW (2

units of 300 MW) and an average output of 3.6 billion kWh/year. The average daily consumption of the plant is about 6,000–8,000

tons of coal, equivalent to 416.8 g of coal/kWh. In the future, there will be 2 more units to operate with a total capacity of 1,200 MW (Nghi Son 2 Thermal Power Plant), to consume about 18,000 tons of coal/day, and to have ash amount of about 1.5 million tons/year, containing 0.306 tons of Hg and 0.36 tons of As. The production wastewater of thermal power plants is mainly from burning coal that contains BOD₅, T-N, phenol, cyanide (CN⁻) and thiocyanate (SCN⁻). The number of workers for the 2 plants is about

1,200 persons. The pollutant load of the two plants is calculated in table 11.

The burning of coal in thermal power plants discharges organic matters, nitrogen, phenol, cyanide and thiocyanate into water. Wastewater needs to be thoroughly treated to avoid the risk of ecosystem degradation. The increase of organic matters and nitrogen will cause eutrophication and lessen dissolved oxygen [13] while the presence of toxic chemicals will impact on sensitive ecosystems [14].

Table 11. Pollution load from Nghi Son 1 and 2 Thermal Power Plants (ton/year)

Pollutants	Before treatment			After treatment		
	D.W	P.W	Total	D.W	P.W	Total
COD	34.75	40,996.8	41,031.6	13.90	3,153.60	3167.5
BOD ₅	21.72	25,623.0	25,644.7	4.34	1,971.00	1,975.3
T-N	3.96	22,995.0	22,999.0	1.98	22,995.00	22,997.0
T-P	1.12	0.0	1.1	0.78	0.00	0.8
NO ₃ + NO ₂	0.04	230.0	230.0	0.02	229.95	230.0
NH ₄ ⁺	0.95	5,518.8	5,519.8	0.48	5,518.80	5,519.3
PO ₄ ³⁻	0.50	0.0	0.5	0.35	0.00	0.4
TSS	47.04	0.0	47.0	2.35	0.00	2.4
Phenol		1,839.6	1,839.6		354.78	354.8
CN ⁻		4,007.7	4,007.7		98.55	98.6
SCN ⁻		13,797.0	13,797.0		394.20	394.2

Notes: D.W: Domestic wastewater; P.W: Production wastewater.

Pollution load from Nghi Son petroleum refinery

Nghi Son petroleum refinery project with over 9 billion USD and capacity of 200,000

barrels/day, equal to 10 million tons/year and about 20,000–30,000 employees, started its operation in May 2018. The pollution load of Nghi Son oil refinery is estimated in table 12.

Table 12. Pollution load from Nghi Son petroleum refinery (ton/year)

Pollutants	Before treatment			After treatment		
	D.W	P.W	Total	D.W	P.W	Total
COD	724.0	3,152.0	3,876.0	289.6	472.8	762.4
BOD	452.5	1,970.0	2,422.5	90.5	98.5	189.0
T-N	82.5	205.0	287.5	41.3	102.5	143.8
T-P	23.3	0.0	23.3	16.3	0.0	16.3
NO ₃ + NO ₂	0.8	2.1	2.9	0.4	1.7	2.2
NH ₄	19.8	49.2	69.0	9.9	41.8	51.7
PO ₄	10.5	0.0	10.5	7.3	0.0	7.3
TSS	980.0	581.0	1,561.0	49.0	58.1	107.1
Oil	0.0	749.0	749.0	0.0	112.4	112.4
Phenol	0.0	38.0	38.0	0.0	38.0	38.0
Sulfite	0.0	20.0	20.0	0.0	20.0	20.0
Cr	0.0	4.9	4.9	0.0	4.9	4.9

Notes: D.W: Domestic wastewater; P.W: Production wastewater.

Pollution load from brick production industry

Up to 2017, four large brick production enterprises in Nghi Son EZ were constructed, including: (1) Truong Lam Brick Factory (capacity of 15 million bricks/year); (2) LIGOGI Truong Lam Brick (capacity of 10 million bricks/year); (3) Truong Son Tunnel Brick (capacity of 30 million bricks/year); (4)

the Unburnt Brick (capacity of 100 million bricks/year). Brick production generates mainly wastes of dust and smoke emission. Wastewater is mainly from domestic activities of more than 3,000 employees working for the enterprises. Calculation results of pollution load from domestic wastewater of factories are presented in table 13.

Table 13. Pollution load from domestic wastewater of brick production industry in Nghi Son EZ (ton/year)

Pollutants	Before treatment					After treatment				
	Truong Lam	LIGOGI Truong Lam	Truong Son	Unburnt brick	Total	Truong Lam	LIGOGI Truong Lam	Truong Son	Unburnt brick	Total
COD	6.37	9.56	19.11	63.71	98.75	2.55	3.82	7.65	25.48	39.50
BOD	3.98	5.97	11.95	39.82	61.72	0.80	1.19	2.39	7.96	12.34
T-N	0.73	1.09	2.18	7.26	11.25	0.36	0.54	1.09	3.63	5.63
T-P	0.20	0.31	0.61	2.05	3.17	0.65	0.14	0.21	0.43	1.44
TSS	8.62	12.94	25.87	86.24	133.67	1.96	0.43	0.65	1.29	4.33
NO ₃ + NO ₂	0.01	0.011	0.022	0.073	0.11	0.00	0.01	0.01	0.04	0.06
NH ₄	0.17	0.26	0.52	1.742	2.70	0.40	0.09	0.13	0.26	0.88
PO ₄	0.09	0.138	0.28	0.92	1.43	0.06	0.10	0.19	0.64	1.00

Total pollution load of industrial activities in Nghi Son EZ

The total pollution load from industrial activities in Nghi Son EZ (both phases 1 and 2) before and after treatment scenarios is summarized in table 14, 15.

Every year, industrial activities in Nghi Son EZ discharge about 13 thousand tons of COD, 3.7 thousand tons of BOD₅, 27.4 thousand tons of N (including 7.6 thousand tons of dissolved nitrogen), 967.8 tons of P and nearly 12.3 thousand tons of TSS into the coastal area. If the wastewater is not treated, the amount of pollutant is even higher, including 99 thousand tons of COD, 51 thousand tons of BOD, 31.8 thousand tons of N (with 7.9 thousand tons of dissolved nitrogen), 1,294 tons of P, more than 123 thousand tons of TSS. Besides, the wastewater also contains phenol, cyanide, thiocyanate and heavy metal.

Most of the enterprises mentioned above are already in operation, except for some that are neither operating at full capacity as their designs and licenses nor full facilities such as the enterprises of steel, thermal power and cement. The group of thermal power plants produces the largest pollutant amount of organic and nitrogen, followed by vegetable oil production, Nghi Son Steel, wood processing and POMIDO Steel. These enterprises also generate a huge number of suspended solids. Cement plants discharge a great number of dissolved solids, while steel plants discharge mainly heavy metals, sulfate and chloride. Some other typical pollutants are found, such as sulfites from petroleum refinery, cyanide and thiocyanate from thermal power plants and oil and grease from vegetable oil and steel rolling factories.

Table 14. Pollution load from industrial activities of Nghi Son EZ - before treatment (ton/year)

Pollutants	Cong Thanh Cement	Nghi Son Cement	Nghi Son Beer	Brick production	Vegetable oil	Wood processing	Seafood processing	Oil refinery	Nghi Son Steel	POMIDO Steel	Thermal power	Total
COD	292.9	228.8	833.5	98.75	35,434.8	6,893.4	795.0	3,876.0	6,953.8	2,319.3	41,031.6	99,153.3
BOD ₅	88.6	80.5	324.1	61.72	13,640.0	2,656.2	318.0	2,422.5	4,508.6	1,502.4	25,644.7	51,402.3
T-N	29.0	23.2	160.7	11.25	6,845.1	1,334.6	33.3	287.5	19.8	13.2	22,999.0	31,809.8
T-P	2.6	2.9	13.7	3.17	575.2	112.7	13.8	23.3	405.6	133.7	1.1	1,294.4
NO ₃ +NO ₂	29.6	0.2	1.6	0.11	68.5	13.3	0.3	2.9	0.2	0.1	230.0	317.9
NH ₄ ⁺	3.9	4.2	38.6	2.70	1,642.8	320.3	8.0	69.0	4.8	3.2	5,519.8	7,630.6
PO ₄ ³⁻	1.2	1.1	6.1	1.43	258.9	50.7	6.2	10.5	182.5	60.2	0.5	582.1
TSS	2,097.5	1,435.1	136.6	133.67	13,484.2	4,257.0	438.1	1,561.0	75,130.8	24,424.8	47.0	123,381.2
TDS	1,535.6	1,015.9							0.0	0		2,551.5
Oil	1.1	0.7			15,384.8			749.0	7,840.0	2,548		26,523.6

Table 15. Pollution load from industrial activities of Nghi Son EZ - after treatment (ton/year)

Pollutants	Cong Thanh Cement	Nghi Son Cement	Nghi Son Beer	Brick production	Vegetable oil	Wood processing	Seafood processing	Oil refinery	Nghi Son Steel	POMIDO Steel	Thermal power	Total
COD	53.2	49.2	128.6	39.50	5,318.1	1,076.3	157.5	1,550.4	1,086.5	376.9	3,167.5	13,003.7
BOD ₅	7.9	9.6	17.6	12.34	683.1	139.7	24.7	484.5	241.7	86.0	1,975.3	3,682.4
T-N	14.5	11.6	80.3	5.63	3,422.5	690.8	19.8	143.8	9.9	6.6	22,997.0	27,402.4
T-P	1.9	2.0	10.2	1.44	431.4	87.5	12.2	16.3	303.9	100.1	0.8	967.8
NO ₃ +NO ₂	0.1	0.1	1.4	0.06	58.2	11.7	0.3	1.4	0.1	0.1	230.0	303.5
NH ₄ ⁺	3.5	3.0	32.6	0.88	1,396.3	281.6	7.5	34.5	2.4	1.6	5,519.3	7,283.2
PO ₄ ³⁻	0.7	0.8	4.6	1.00	194.1	39.4	5.5	7.3	136.8	45.0	0.4	435.6
TSS	207.2	139.5	12.7	4.33	1,347.6	439.3	48.0	107.1	7,512.5	2,441.9	2.4	12,262.6
TDS	743.8	556.2			0.0				0.0	0.0		1,300.1
Oil	1.7	1.3			2,370.7			749.0	150.0	48.8		3,258.4

CONCLUSIONS

Untreated wastewater from industrial activities in Nghi Son EZ contained the large amount of pollutant discharged into the coastal waters every year, including 99 thousand tons of COD, 51 thousand tons of BOD₅, 31.8 thousand tons of N (including 7.9 thousand tons of dissolved nitrogen), 1,294 tons of P, 123 thousand tons of TSS. In case of treated wastewater, the amount of pollutant is still very high, consisting of 13 thousand tons of COD, 3.7 thousand tons of BOD₅, 27.4 thousand tons of N (including 7.6 thousand tons of dissolved nitrogen), 967.8 tons of P and nearly 12.3 thousand tons of TSS. Besides, phenol, cyanide, thiocyanate and heavy metal were detected. The factories that cause high pollution are thermal power, steel rolling, vegetable oil production, wood processing and cement production. Due to no centralized wastewater treatment facilities, it is very important to control treatment efficiency of wastewater and the discharges from factories in Nghi Son EZ.

The pollution load estimation is still limited due to the lack of information and documents related to factories in Nghi Son EZ and underestimation of all other small industrial sectors. However, the pollution load assessment hopefully gives the environmental managers and the Management Board of Nghi Son EZ an overview of waste discharge status in the area, with the purpose of implementing proper measures to manage the discharge sources.

Acknowledgements: The research funding from project “Study on application of the high and average resolution and multi-temporal remote sensing data for integrated assessment of environmental hazards in the North Central Coast” (Code number: VT-UD-02/17–20) is acknowledged.

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