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연구논문

Environmental Impacts of Port and Industrial Development Along the Thi Vai River

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Abstract

Ba Ria - Vung Tau province in Southern Vietnam is one of the fastest economic growing areas in the country, characterized by the rapid port and industrial development along the Thi Vai river. The socio-economic situation of the area has generally been improved; however, its part of the local inhabitants has not gained benefits from the changes. 35 surface water samples and 25 sediment samples were analysed with the interpretation of the SPOT images for 1995 and 2005. The data showed that rapid port and industrial development have resulted in significant losses of mangroves and agriculture land. The surface water was seriously polluted, particularly in terms of organic materials and suspended solids. It contained high and increasing oil concentrations. The river sediment was saline and slightly alkaline. It was heavily reduced, organic-rich, and contaminated with oil and heavy metals (Cu, Pb, and Cr).

Keywords : Port, industrial zones, pollution, surface water quality, sediment quality, land use changes, remote sensing, GIS, SPOT images, Vietnam

I. Introduction

Ba Ria - Vung Tau province in Southern Vietnam is one of the fastest economic growing areas in the country, characterized by the rapid port and industrial development along the Thi Vai river. Port and industry play a key role in economic growth, but the concentration of the port and industrial activities along the Thi Vai river also has disadvantages. By they are situated in sensitive ecosystems such as estuaries or wetland. Consequently, almost all port and industry activities are the major sources of pollution, such as degradation of the water and sediment quality, impact landuse and effect on human health.

This paper aims at characterizing the surface water quality, river sediment quality, and land use change near port and industrial development along Thi Vai river. It also describes the relationship between port and industrial development

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and pollution.

II. Materials and Methods

1. Area description

The study area is a rectangular zone of 43 by 16 km of which the corner point coordinates are approximately (Figure 1):

(1) E107°12′/N10°22′

(2) E107°03′/N10°18′

(3) E106°54′/N10°41′

(4) E107°03′/N10°45′

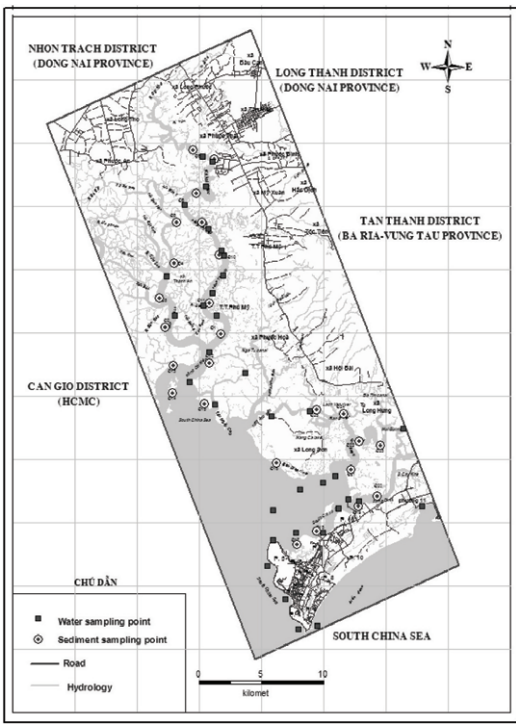

Figure 1. Location of the study area and the sampling sites

This study area is located in the vicinity of one of the largest natural river and mangrove systems. Important infrastructure developments along the Thi Vai include industries, economic processing zones, storage areas, port terminals, and ect.

2. Data collection and analysis

1) Sampling

The surface water was sampled at 35 sites (Figure 1) for 7 conseccutive months (July 2005-February 2006, August 2005 missing). The sampling sites were selected on the basis of the main impacting pollution sources (ports, industrial zones, and ect.). The sites are then divided into 7 groups (the Thi Vai area, the Go Gia area, the Cai Mep area, the Ganh Rai area, the Vung Tau - 1, the Vung Tau-2 and the aquaculture) depending on their relative locations with respect to the pollution sources, the nature of pollution and the use of the water resources.

The sediment was sampled at 25 sites (Figure 1). Samples were collected on June 18th and 20th, 2005. Sampling sites were determined in the river at a distance of approximately 50-100 from the river bank. Then samples were taken to a depth of 20 cm using a hand - driven borer.

2) Analysis

The parameters and methods using analysed for sediment samples and water surface samples (Table 1).

Table 1. The parameters and methods using analysed

Items	Water quality	Sediment quality
Parameters	pH, EC, salinity, DO, temperature, E.coli, DDT, DDE, lindane, Cl^-, SO_4^{2-}, Al^{3+}, PO_4^{3-}, NO_2^-, NO_3^-, NH_4^+, SS, Colour, COD, BOD, Total Fe	pH(1/2.5),EC(1.5), EC(e) OM, Al3+, dissolved SO42-, Cl-, Soluble cations(Ca, Mg, Na, K), Exchangeable cations(Ca, Mg, Na, K), Fe2+, Fe3+, Mn2+, Oil and grease
Methods	Methods of analysis for sea water , Standard methods waste water	Methods of analysis for marine sediments, Standard methods for the Examination of water and

The land use changes are showed using the analysis SPOT images, field trip for ground truth check, a questionnaire, and GPS. The image analysis uses SPOT images taken in 1995 and 2005.

III. Results

1. Surface water quality

1) pH and salinity

The water environment ranges from slight to neutral alkaline (pH: 7.53). The Thi Vai area (the uppermost part) shows the lowest pH (6.93) while the Vung Tau-2 area (near the sea) shows the highest value (8.04) (Figure 2). This is a sign of tidal influence observed in coastal areas.

Salinity shows a large range and a clear seasonal pattern ($p<0.001$); the wet season exhibits lower values than the dry season.

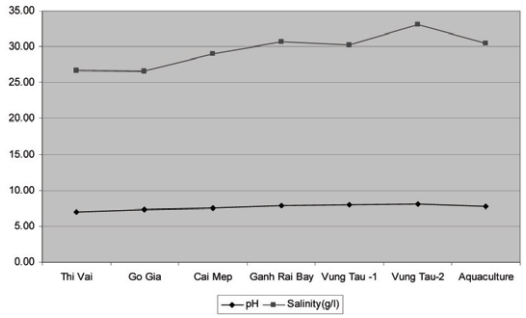

Figure 2. Variations of pH and salinity between the areas

2) Organic pollution

The surface water is subject to high levels of organic pollution. The variables indicating this type of pollution (COD, colour, NO^{2-}, NO^{3-}, NH^{4+}, and PO_4^{3-}) show high values. This is coherent with the low values of DO (3.89 mg/l). However, the BOD (a good indicator for organic pollution) concentrations are low (2.00 mg/l). This can be interpreted that most of the pollutants are recalcitrant, and not likely to be broken down by the microbial activities. This phenomenon is closely related to the characteristics of the industrial discharges in the study area (most popularly the chemical industry, cement industry, oil and gas industry, mechanical industry, steel industry, ship building and repairing, light industry (textile, sewing, stationery), and port related industry (baobariavungtau.com.vn, 2006). Comparison with data from the past shows that organic pollution in the area has recently increased (Table 2).

Table 2. Comparison of current pollution with data from the past

Variable	SS (mg/l)	DO (mg/l)	COD (mg/l)	NH_4^+ (mg/l)
Year 1999[a]	0	4.8-5.6	-	0.21-0.44
Year 2003[b]	17.7-51.7	1.05-4.10	95-1 094	2.3-3.7
Year 2005-2006	337-1 264	0.1-7.64	1 122-2 529	0.01-4.20
TCVN 5945-1995 (B-level)[c]	100	-	100	1

a: Vien Ky thuat nhiet doi va Bao ve moi truong (1999)
b: Department of Environment and Resources of Ba Ria-Vung Tau (2004)
c: industrial wastewater containing the values of parameters and concentration of substances lower than (or equal to) those specified in the B-level of the standard can be discharged into waters used for waterway transport, irrigation, swimming, aquaculture.

3) Bacterial pollution

To measure the microbiological pollution level, E.coli is used as an indicator. Ecoli is found in the surface water in the study area. The E.coli concentration in the aquaculture area is the highest (283.71 CFU.100ml-1) compared to the other areas because of the nature of aquaculture discharge. Some individual samples of the bathing area (Vung Tau-1 and Vung Tau-2) exceed the standards; this might result in a risk of diarrhea, eye, and ear infections.

4) Metal pollution

Metal contaminants in water bodies can affect human health and aquatic organisms. Most of the metal values are lower than both Vietnamese standards (TCVN 5942-1995, TCVN 5945-1995), except for Pb and Barium.

5) Oil pollution

The surface water in the port contains high concentration of oil (3.6 mg/l). The mean oil value exceeded the Vietnamese standard (TCVN 5943-1995 for bathing and aquaculture purposes). The site that showed the highest oil concentration (5.9 mg/l) near the Petroleum port.

From the past in the study area, it showed that oil concentration in the surface water has increased over time (Figure 3). They increased especially in 2005, which probably is a result of the increasing ship traffic related to the port developments and the offshore oil platform industry. With unchanged policy and management, the severity of the problem will significantly increase in the future. There is an urgent need for appropriate measures to cope with the oil problem, due to the vast impacts of oil pollution on the environment.

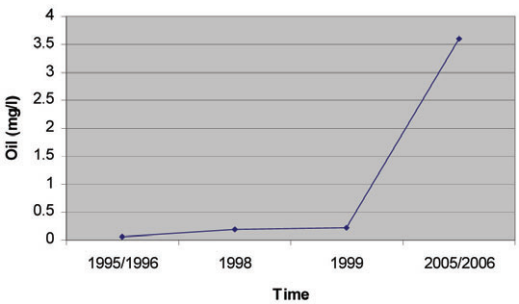

Figure 3. Oil concentrations in the water of the study area during the period 1995-2006

Sources: 1995/1996 (RDCPSE, 1996), 1998 (RDCPSE, 1998), 1999 (Vien ky thuat nhiet doi va bao ve moi ttuong)

6) Cumulative impacts of pollution

The downstream parts of the main rivers in the study area, particularly Thi Vai river, have experienced heavy pollution. In the context of vigorous expansion of ports and industrial zones, associated with heavy waterway traffic and rapid urbanisation, the situation is likely to get worse.

Pollutants flowing out to the sea are hindered by the tidal impacts. This makes a large downstream area subject to pollution. Down to the sea, pollution level has remarkably decreased due primarily to (i) longer distances from the pollution sources, (ii) assimilation of the pollutants by the natural system (water, sediment, biota), and (iii) higher water exchange near the sea. In the future, when many ports from Ho Chi Minh City are relocated along the Thi Vai river, in combination with the rapid economic development of the area (Viet Nam Environment Protection Agency, 2004), the water quality problem will be more serious.

2. River sediment quality

For sediment quality, no Vietnamese standards have been published. Wherever possible, the observed results are compared with the Canadian guidelines.

The river sediment is slightly alkaline (pH(1/2.5)=7.39) and of large salinity variation (ECe: 17.28-28.80, mean: 24.58 mS/cm). It contains high amounts of organic material (OM: 12%-39.8%). Concentrations of the major soluble cations are low (Ca: 34.10; Mg: 43.14; K: 95.27 mg/100g), except for Na (1 683.85 mg/100g); however, the changeable form of these are high. The concentrations of ferrous ion (Fe^{2+}) are high (870.66 mg/100g), which is about ten times as high as the ferric ion (Fe^{3+}) (87.05 mg/100g),

resulting in a high Fe^{2+}/Fe^{3+} ratio. The soluble and exchangeable forms of Mn are low (respectively 0.05 and 0.18 mg.100g-1) while the acid-extracted Mn show high values (2.58-77.52 mg/100g). The Cl- concentrations are high, ranging from 1,418 to 2,658.75 mg.100g-1. The dissolved SO_4^{2-} ranges from 8.2 to 223.56 mg/100g. The concentrations of Al^{3+} are low (1.22 mg/100g). The total oil and grease concentrations are high in the analysed samples (1.26-14.14 mg/100g).

1) Pollution of metals

Soluble and exchangeable manganese (Mn) concentrations are low respectively 0.05 and 0.18 mg/100g) while the acid-extracted Mn is high (2.58-7.52 mg/100g). This suggests that Mn is strongly bound to the sediment and the organic matter.

The concentrations of Fe^{2+} are high (870.66 mg/100g), about ten times as much as the Fe^{3+} concentrations (87.05 mg/100g). The ratio Fe^{2+}/Fe^{3+} is always lower than 1. This means that reduction conditions predominate and the Fe^{2+} cations are bound and fixated in the sediment layers.

Aluminum (Al) is an indicator for the acidity of the environment and ranges in these river soils from 0.00-4.30 mg/100g. In reduced conditions, Al is adsorbed onto the organic complexes of the clay fractions in the sediment.

2) Oil pollution

Oil is found at all the sampling sites (1.26-14.14 mg/100g). Oil is also found in other port areas or areas where oil exploitation and transport is going on. Oil pollution is a serious problem in the study area, both in the surface water and the sediment. Oil spilled in the surface water can accumulate in the sediment through several processes (US National Research Council Committee on Oil in the Sea, 2003). Oil pollution is always harmful to the environment (El Tarabily, 2002; IPIECA, 2005)

3) Cumulative impacts of pollution

Pollution is a real problem in the study area. The causes of pollution (ports, industrial zones, waterway traffic, urbanisation) expand fast; thus, the environmental quality of the main rivers in the study area decreases.

Besides the local sources, contribution to pollution from upstream of the study area is significant (Vietnam Environment Protection Agency, 2004). In 1998, the Thi Vai river experienced high levels of organic pollution due primarily to wastewater disposal from Ho Chi Minh city where oil pollution was very common and Dong Nai province (Trinh *et al*., 1998). Currently the Thi Vai river receives nearly 20,000 m3/day of untreated industrial wastewater from Dong Nai province (www.nld.com.vn, 2006). The study area acts as a sink for pollutants from the upperstream Ho Chi Minh city and Dong Nai province. Tides influence the residence time of the pollutants in the study area. This results in a large downstream area subject to pollution. In the future, continuing economic development of the area will worsen this situation.

3. Land use changes

The study area has 6 main land use groups: Agriculture (rice, annual crops, long term tree, rubber), forest (nature forest and plantation forest), specialized land (specialized land, saltmarsh), aquaculture (shrimp monoculture, shrimp-forest), settlement (settlement-garden), and wasteland.

1) Land Use in 1995

On the 1995, 12 land use categories were identified, 25.16% of the study area is used for agriculture, of which permanent tree crops occupy almost half of the land. Natural forest occupies 12.16% of the study area. Settlements and gardens followed the main roads. Specialized land uses (settlement infrastructure) occupy only 1.47% of the study area. Shrimp forest were not present (Figure 4).

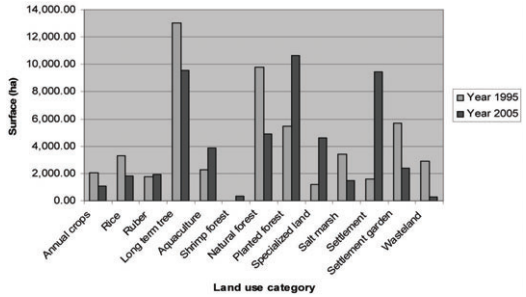

Figure 4. Land use category in 1995 and 2005

2) Land Use in 2005

The 2005 photograph revealed 13 land cover categories, the new one being shrimp forests (0.44% or 352.40 ha) scattered in the forest area. By 2005 agriculture had decreased to 18.03%. Plantation forest occupies 13.23% and natural forest occupies 6.12%. Settlements increased by 11.73%. Specialized land uses had increased by 5.77% or 4,628.94 ha (Figure 4). Industrial zones are visible on the SPOT image of 2005.

3) Land Use Changes between 1995 and 2005

From 1995 to 2005, the study area seriously changed in land cover (Figure 4). Agriculture decreased by 28.41% or 5,739.55 ha, mainly through the conversion of rice areas to settlements and port and industrial infrastructure. Aquaculture increased by 35.95% or 1,573.15ha. Natural forest areas decreased by 27.13% or 4,849.35 ha because of the port and industrial developments; but, plantation forests increased by 95.13% between 1995 and 2005, mostly during the last 5 years. Wasteland decreased by 89.41% or 2,591.61 ha over the 10 years through conversion to forest plantations.

About 3,452.25 ha of specialized land (the port and industrial) was created over the 10 years. The expansion of the port and industrial area can readily be seen.

The mangrove are decreased due to port and industrial zone developments. Reforestations occur but the natural biodiversity still decreases; fragmentation of mangrove forests is observed.

IV. Discussion

The development of port and industry has an outspoken socio-economic benefit; however, it also causes serious impacts on the ports' surrounding marine and river-mouth ecosystems. Significant impacts are the destruction of habitats and the landscape, water pollution, and sediment degradation.

The surface water has been influenced by several pollution sources, mainly ports and industries. Besides, contribution of pollution from upstream parts is also worth noticing. Organic pollution is one of the most serious aspects of water pollution. Bacterial contamination (E.coli) and the toxic heavy metals (Pb, Hg, and Ba) are also of special concerns. Pollution levels are influenced by the seasonal rainfall pattern and decrease down to the open sea. Measures to safeguard the environment are imperative and must soon be implemented to minimise the environmental impacts.

In the study area the sediment concentrations

of iron, manganese, oil and heavy metals are high. Contamination with oil and heavy metals is documented. The generation of toxic substances in the sediment is likely.

The land use changes over time show an increase of human construction and infrastructure i.e. road construction, industrial zones and port development. The total forest area in 2005 does not differ substantially from the total area in 1995, but the quality of the mangrove area certainly deteriorated from 1995 to 2005. The port and industrial area increased by 293.39% from 1995 to 2005, but mainly during the last years.

V. Conclusions

Rapid port and industrial development in Thi Vai river has generated several physical and socio-economic impacts. The former has included land use changes, and alteration of water and sediment quality while the latter has involved in a rapid urbanization. River water has been contaminated by organic materials, heavy metals, and oil. The sediment is heavily anoxic and contaminated by heavy metals and oil. Major land use changes have been observed. The areas of agriculture, original mangrove forests, and wastelands have been significantly reduced. However, specialized and settlement areas around the development area have been increased. This is because of a huge demand of lands for the ports and industrial zones in the province. The human population has also increased remarkably around the port and industrial areas, which has in turn posed negative impacts to the surroundings.

* This is the revision of the paper from Vietnamese and Korean Experiences in Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) which was published in the Vietnam-Korea Workshop on August 21, 2009.

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