

CHANGES OF BENTHIC MACROINVERTEBRATES IN THI VAI RIVER AND CAI MEP ESTUARIES UNDER POLLUTED CONDITIONS WITH INDUSTRIAL WASTEWATER

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Abstract

The pollution on the Thi Vai River has been spreading out rapidly over the two last decades caused by the wastewater from the industrial parks in the left bank of Thi Vai River and Cai Mep Estuaries. The evaluation of the benthic macroinvertebrate changes was very necessary to identify the consequences of the industrial wastewater on water quality and aquatic ecosystem of Thi Vai River and Cai Mep Estuaries.

In this study, the variables of benthic macroinvertebrates and water quality were investigated in Thi Vai River and Cai Mep Estuaries, Southern Vietnam. The monitoring data of benthic macroinvertebrates and water quality parameters covered the period from 1989 to 2015 at 6 sampling sites in Thi Vai River and Cai Mep Estuaries. The basic water quality parameters were also tested including pH, dissolved oxygen (DO), total nitrogen, and total phosphorus. The biodiversity indices of benthic macroinvertebrates were applied for water quality assessment.

The results showed that pH ranged from 6.4 – 7.6 during the monitoring. The DO concentrations were in between 0.20 – 6.70 mg/L. The concentrations of total nitrogen and total phosphorus ranged from 0.03 – 5.70 mg/L 0.024 – 1.380 mg/L respectively. Macroinvertebrate community in the study area consisted of 36 species of polychaeta, gastropoda, bivalvia, and crustacea, of which, species of polychaeta were dominant in species number. The benthic macroinvertebrates density ranged from 0 – 2.746 individuals/m² with the main dominant species of *Neanthes caudata*, *Prionospio malmgreni*, *Paraprionospio pinnata*, *Trichochaeta carica*, *Maldane sarsi*, *Capitella capitata*, *Terebellides stroemi*, *Euditylia polymorpha*, *Grandidierella lignorum*, *Apeudes vietnamensis*. The biodiversity index values during the monitoring characterized for aquatic environmental conditions of mesotrophic to polytrophic. Besides, species richness positively correlated with DO, total nitrogen, and total phosphorus. The results confirmed the advantage of using benthic macroinvertebrates and their indices for water quality assessment.

Key words: Thi Vai River, industrial wastewater, benthic macroinvertebrates, water quality.

1 INTRODUCTION

Macroinvertebrates are those animals that lack a backbone and are just visible to the naked eye, or more than 0.2 mm in diameter. Benthic macroinvertebrates are those organisms that occur in or on the bed of rivers, including those parts in deep water away from the littoral zone [1, 2]. The deepwater benthos includes the same major groups as that of the littoral zone, but is usually less diverse. Most deepwater species are deposit feeders that consume small particles of organic matter or filter feeders that remove particles from the water column. Of the biomonitoring advantages reported in the scientific literature, the ones that specifically apply to benthic macroinvertebrates are that they have limited mobility and reflect local conditions, and that because some species are long lived they may reflect conditions that are not chronic problems [1, 2, 3, 4, 5]. The distribution and diversity of benthic macroinvertebrates were strongly influenced by not only a single physical or chemical parameter but rather by the combination of environmental factors [6]. Benthic macroinvertebrates have been used widely in bioassessment activities primarily in temperate areas. On the other hand, these animals were used for development an ecological indices to assess the running water quality in term of nutrient enrichment in Europe and North American [7, 8, 9, 10]. In tropical countries, benthic macroinvertebrates closely related to the degradation of water quality and their community diversity correlated with polluted status in aquatic environment [6]. Several groups of benthic macroinvertebrates could be used as indicators for organic pollution whereas all groups of these animals could be applied for rapid assessment methods for macroinvertebrates in Brazil, Ghana, and Thailand [6, 11].

The Thi Vai River is a tributary of the Dong Nai River System. It flows for 76 km through the two southern provinces of Dong Nai, Ba Ria – Vung Tau and Ho Chi Minh City (HCMC) with 400 – 600 m width and 12 – 20 m depth (the deepest site ~ 60 m). The amplitude of tides at this river was very high, sometimes it was highly varied over 400 cm with fast flows [12, 13]. The salinity of Thi Vai River fluctuated from 24 to 32‰ in the dry season, and from 14 to 28‰ in the rainy season [12]. This resulted from the small freshwater sources, so the Thi Vai had the characteristics of salt-water bay. Therefore, the aquatic ecosystem of Thi Vai River and Cai Mep Estuaries belonged to the marine ecosystem.

The organic pollution in Thi Vai River and Cai Mep Estuaries has recently become a matter of particular importance to the relevant and local authorities. The evaluation was conducted by researchers from the Institute of Environment and Resources and concerned agencies basing on polluting elements in the river that caused harmful effects on farmers in HCMC, Dong Nai and Ba Ria – Vung Tau Provinces [12, 13, 14]. Researchers also found high contamination of organic polluting substances in the 76-kilometer river. Concentration of other polluting elements is also up to eight times the allowed levels in Vedan, Go Dau and Phu My Ports [14].

However, the impact of industrial wastewater from the enterprises from along the left bank of Thi Vai River and Cai Mep Estuaries on the aquatic ecosystem has not been considered completely. Therefore, the evaluation of the benthic macroinvertebrate changes was very necessary to identify the consequences of the industrial wastewater from industrial parks such as Vedan, Go Dau, Phu My, My Xuan, Cai Mep,... on the aquatic ecosystem. The objective of this study is to evaluate the changes of benthic macroinvertebrate communities in Thi Vai River and Cai Mep Estuaries under polluted conditions with industrial wastewater.

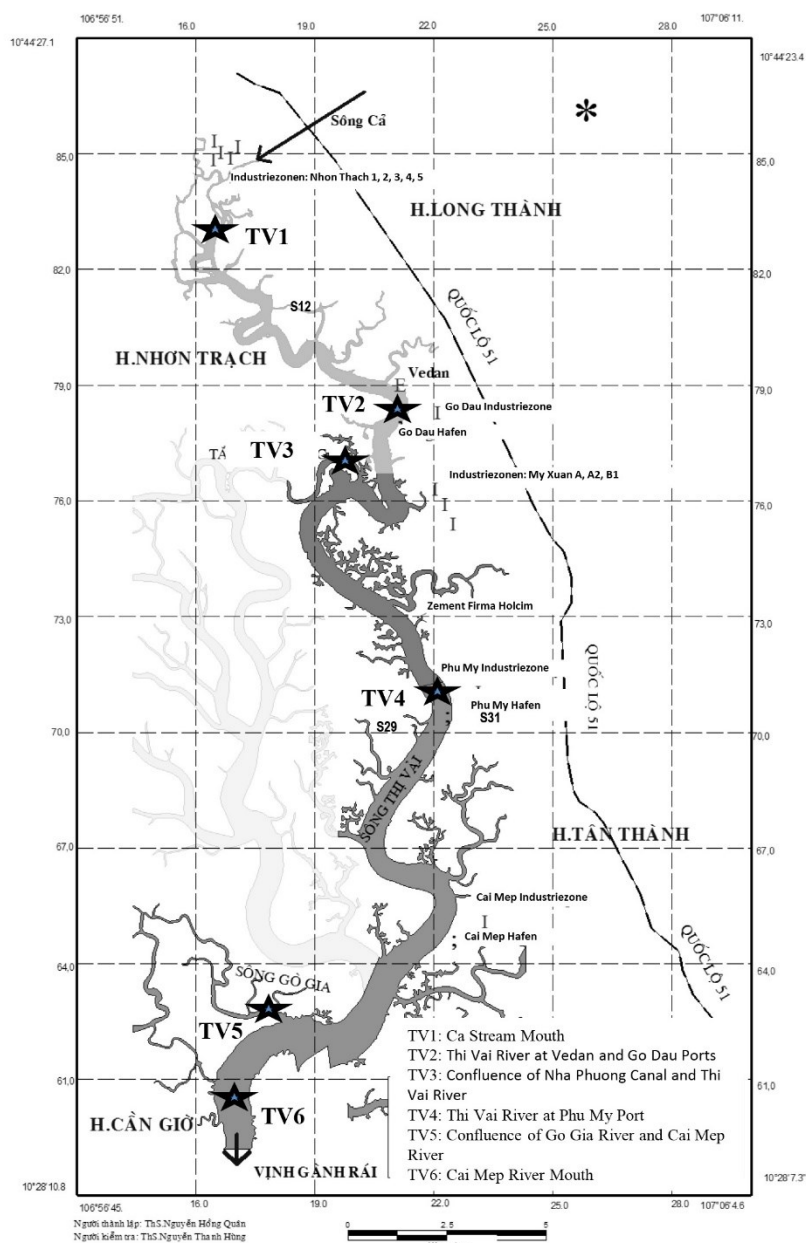


Figure 1. Thi Vai River and Cai Mep Estuaries with 6 sampling sites (TV1-TV6).

2 MATERIALS AND METHODS

2.1 Study Area and Sample Collection

The Thi Vai River begins from Nhon Tho Village, Long Thanh District of Dong Nai Province, runs through Tan Thanh District of Ba Ria – Vung Tau Province and Can Gio District of HCMC before pouring into the Eastern Sea. Its total basin area is some 300 square kilometers. The river has not only received some 34,000 cubic meters of untreated wastewater discharged daily from nearly 200 operating companies along the basin, but it has also received a large amount of untreated wastewater from residential areas and cattle-breeding farms [14].

The monitoring data of benthic macroinvertebrates and water quality parameters collected in the period from 1989 to 2015 at 6 sampling sites in Thi Vai River and Cai Mep Estuaries (*Figure 1*).

The samples for water quality analysis in the field were collected according to the Operational Guide (3rd Ed.), UN Environment Programme (1992) [15]. Sample locations at each site were taken in the middle of the river with depth layer of surface water from 30 – 40 cm. The water samples were collected in 2 liter plastic bottles and kept at 2^oC temperature [15].

Sample locations of benthic macroinvertebrates at each site were selected in each of the right and left parts of the river. Five locations were sampled at each of these parts of the river [3, 4, 12, 13]. According to working experiences in studied area, the middle of river need not be sampled because of without change to collected data.

Prior to sampling, all the equipment to be used was thoroughly cleaned to remove any material left from the previous sampling site. At each sampling location, a composite of four grabs was taken with a Petersen grab sampler, covering a total area of 0.1 m². If the sampler did not close properly because material such as wood, bamboo, large water-plants, or stones jammed its jaws, its contents were discarded and another grab was taken [3, 4, 12, 13].

The composite sample was washed through a sieve (0.3 mm) with care taken to ensure that macroinvertebrates did not escape. The contents of the sieve were then placed in jars and fixed with formaldehyde. Samples were sorted in the laboratory, because there was insufficient time at a site. The sample jar was labeled with the site location code, date, position within the river, and replicate number. The sampling location conditions, collector's name were recorded on a field sheet [3, 4, 12, 13].

2.2 Physical, Chemical and Benthic Macroinvertebrate Analysis

The aquatic environmental parameters (pH, DO, total nitrogen, total phosphorous) were analyzed according to standard methods (APHA, AWWA, WEF, 2005) [16]. All individuals collected were identified and counted under a compound microscope (with magnifications of 40 – 1200x) or a dissecting microscope (16 – 56x) [3, 4, 12, 13]. The results were recorded on data sheets and specimens are kept at the Ton Duc Thang University, HCMC, Vietnam.

2.3 Data Analysis

For all sites sampled 2007, 2008, 2009, 2010, 2011 and 2015, the following metrics were calculated (which was 1 m²): (i) taxonomic richness (i.e. number of taxa); (ii) abundance (i.e. numbers of individuals per sites); (iv) dominant species; (v) indicator species; (vi) Berger-Parker index [17]; (vii) Shannon-Wiener index [17]; (viii) Pham index [18, 19]; (ix) correlation analysis [12, 20]. Based on the analyses of available data (from 1989) combined with the monitoring of benthic macroinvertebrates in ThiVai River and Cai Mep Estauries from 2007 to 2011 and 2015, the changes of benthic macroiverstebrates in Thi Vai River and Cai Mep Estuaries caused by industrial wastewater were suggested.

3 RESULTS

3.1 General characteristics of benthic macroinvertebrates

3.1.1 Richness

During 2007 – 2011 and 2015, 36 taxa of benthic macroinvertebrates were recorded from the 6 sites. The taxa richness of benthic macroinvertebrates in each survey ranged from 25 – 28 taxa (*Table 1*).

The polychaets was the most species-rich group and occurred in almost sites. In addition, gastropods, bivalves and crustaceans also occurred widely in the studied areas, while ophiuroids appeared in few sites.

Taxa richness at a site ranged widely at the 6 sites sampled in 2007 – 2011, and 2015. Richness ranged from 0 to 15 taxa. The highest richness recorded in the Cai Mep River Mouth (TV6) and the lowest site TV2 (Thi Vai River at Vedan and Go Dau Ports).

Table 1. Numbers of taxa of major groups of benthic macroinvertebrates in Thi Vai River and Cai Mep Estuaries (2007 – 2011, and 2015).

Classes	2007	2008	2009	2010	2011	2015	Total
Polychaeta	15	16	17	16	16	17	21
Gastropoda	1	1	2	1	1	2	3
Polychaeta	15	16	17	16	16	17	21
Bivalvia	2	3	3	3	3	3	4
Ophiuroidea	1	1	1	1	1	1	1
Crustacea	6	6	6	6	5	6	7
Total species	25	27	28	27	26	28	36

3.1.2 Abundance

The number of individuals at 6 sites were highly variable, ranging from 0 to 2,746 individuals/m². The density of benthic macroinvertebrates tended to increase too high or to disappear all in near heavy polluted waters. Similar to taxa richness, the highest density recorded in the site TV6 and the lowest in site TV2.

3.2 Bio-index analysis

The values of bio-indices for the water quality assessment for Thi Vai River and Cai Mep Estuaries from TV1 Site to TV6 Site were presented in *Table 2*.

Table 2. Bio-indices of benthic macroinvertebrate in Thi Vai River and Cai Mep Estuaries (2007 – 2011, and 2015).

Sites	H'	1 – D _{BP}	P
TV1	0.21 – 1.16	0.09 – 0.48	0.00 – 0.28
TV2	0.00 – 0.84	0.00 – 0.33	0.00 – 0.19
TV3	0.17 – 0.98	0.07 – 0.41	0.00 – 0.22
TV4	0.29 – 1.65	0.06 – 0.46	0.00 – 0.27
TV5	0.58 – 2.03	0.16 – 0.60	0.18 – 0.53
TV6	1.26 – 2.94	0.22 – 0.74	0.34 – 0.70

Notes: D_{BP} (Berger-Parker Index); H' (Shannon-Wiener Index); P (Pham Index). Lower values suggest the more pollution.

The change of bio-index values calculated for benthic macroinvertebrates at 6 sites in the ThiVai River was similar. The highest values recorded in the site TV6 and the lowest site TV2. Table 3 showed that the bio-indices tended to separate the more turbid sites (TV1, TV2, TV3 and TV4) with lower values from the more stable sites (TV5 and TV6) with high values of these metrics.

3.3 Changes of environmental variables

To evaluate the changes of water quality in the Thi Vai River, the environmental variables of pH, DO, total nitrogen, and Total phosphorous in Thi Vai River at Vedan and Go Dau Ports were considered. The changes of environmental variables were showed in *Table 3*.

The analysed results showed that the water quality in the Thi Vai River at Vedan and Go Dau Ports was polluted clearly after Vedan Vietnam Enterprise operated one year. Additionally, the wastewater from industrial parks along the left of Thi Vai River have also discharged into this river.

Table 3. Change of environmental variables in Thi Vai at Vedan and Go Dau Ports

Time	pH	DO (mg/l)	Total nitrogen (mg/l)	Total phosphorous (mg/l)
Before the Vedan operated				
09/1989	6.8 – 7.6	6.60 – 6.70	0.03 – 0.45	0.027 – 0.040
07/1994	6.6 – 7.6	4.80 – 6.40	0.50 – 0.81	0.024 – 0.061
After the Vedan operated and mass fish death (02/10/1994)				
10/1994	6.6 – 7.4	0.60 – 4.20	0.77 – 1.73	0.041 – 0.069
03/1995	6.5 – 7.4	0.20 – 3.80	1.21 – 3.02	0.056 – 0.354
10/1995	6.5 – 7.3	0.90 – 4.00	0.71 – 2.12	0.037 – 0.442
03/1996	6.4 – 7.4	0.70 – 3.50	0.71 – 3.31	0.080 – 0.280
10/2002	6.4 – 7.4	0.40 – 1.90	0.74 – 4.50	0.147 – 0.862
04/2003	6.5 – 7.3	0.20 – 1.90	1.28 – 4.74	0.037 – 0.442
09/2003	6.5 – 7.3	0.40 – 2.00	4.21 – 4.60	0.050 – 0.110
09/2005	6.4 – 7.2	0.20 – 1.90	4.20 – 5.70	0.200 – 0.360
2007	6.6 – 7.4	0.30 – 1.20	3.10 – 4.80	1.100 – 1.310
2008	6.6 – 7.5	0.50 – 1.60	3.20 – 4.40	0.890 – 1.050
2009	6.7 – 7.5	0.80 – 1.70	3.01 – 4.20	0.920 – 1.020
2010	6.7 – 7.4	0.70 – 1.60	3.30 – 4.50	0.930 – 1.080
2011	6.6 – 7.4	0.70 – 1.70	3.20 – 4.50	0.920 – 1.070
2015	6.7 – 7.5	1.10 – 1.8	3.08 – 4.30	0.890 – 1.020

3.4 Changes of benthic macroinvertebrates

The changes of benthic macroinvertebrates in Thi Vai River and Cai Mep Estuaries were showed in *Table 4*. After Vedan Vietnam Enterprise operated one year, the benthic macroinvertebrate communities were changed so much. The species number had a tendency to decrease fastly, especially in mollusc and crustaceans. While the density tended to increase too high [12, 13, 18, 19].

After 5 years (1994 – 1999) of water pollution, the smelly black bottom moved far from Vedan Vietnam Enterprise. All benthic macroinvertebrates in Thi Vai at Vedan and Go Dau Ports and surrounding areas died [12, 13, 18, 19]. Additionally, the density of benthic macroinvertebrates in TV1 and TV4 was too high by rich-nutrient water. After 10 years (2003 – 2004) of water pollution, the smelly black bottom expanded to estuary direction. All benthic macroinvertebrates in Thi Vai River from the area upper Vedan and Go Dau Ports 2 km to Muong Canal (5 km downstream of Vedan and Go Dau Ports), including the site TV3 died [12, 13, 18, 19].

Table 4. Change of benthic macroinvertebrates in Thi Vai River and Cai Mep Estuaries

Time	Richness (Taxa/m ²)	Quantity (Individual/m ²)
09/1989	35	50 – 260
06/1990	38	30 – 230
07/1994	36	130 – 220
10/1994	35	10 – 260
10/1995	31	80 – 4,090
03/1999	27	0 – 10,110
09/1999	27	0 – 1,170
03/2000	23	0 – 7,830
09/2000	26	0 – 280
03/2001	24	0 – 890
2007	25	0 – 550

Time	Richness (Taxa/m ²)	Quantity (Individual/m ²)
2008	27	10 – 420
2009	28	10 – 1,360
2010	27	20 – 610
2011	26	10 – 440
2015	28	20 – 740

From 2005 to now, the wastewater from industrial parks (Phu My, My Xuan, Cai Mep,...) along the left of Thi Vai River have discharged in large quantities into this river. Especially, the amount of water used for machine cooling (80 m³/s) from Phu My Power Plants was a one of major cause of change to benthic macroinvertebrates [12, 18, 19].

There was a noticeable event, the benthic macroinvertebrates appeared in Vedan and Go Dau Ports and surrounding areas from 2008 to now [12, 13]. It resulted from the better wastewater control of Vedan Vietnam Enterprise. This proved that aquatic ecosystem and water quality in the Thi Vai River and its branches (flows with strong sea dynamics) will be recover fastly if the waste from factories will be managed hardly.

3.5 Relationships between benthic macroinvertebrates and environmental variables

The taxonomic richness had significant and strong relationships with the water quality variables of DO and total nitrogen ($R^2 = 0.8582 - 0.8656$; $P < 0.05$) (Figure 2). Our finding is in line with previous investigation in which the authors recorded the reduction of taxon rich upon the oxygen concentration decrease in tropical rivers of Brazil [6].

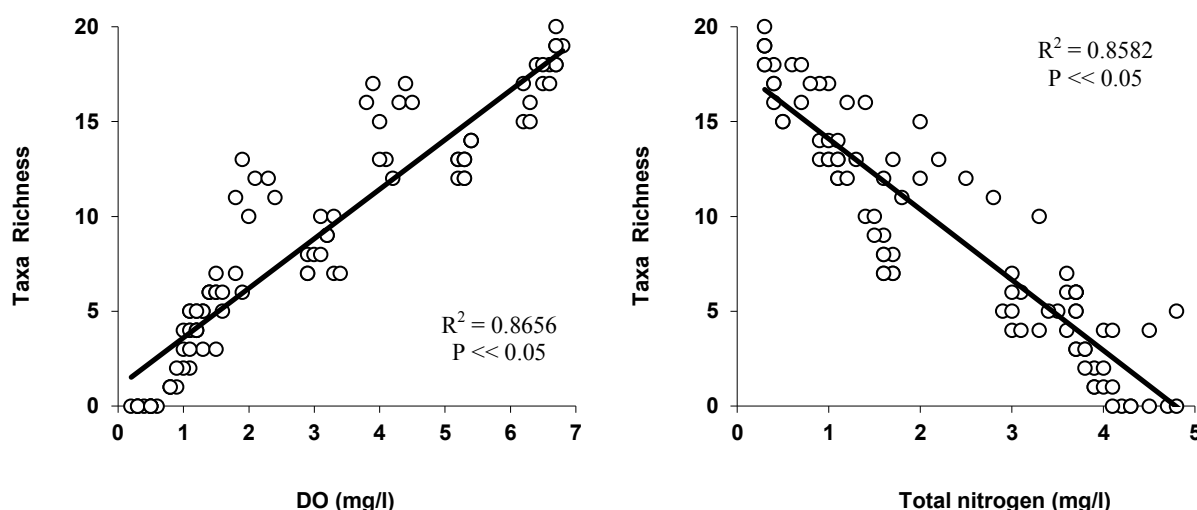


Figure 2. Regression relationship between the taxonomic richness and the water quality variables of DO and total nitrogen for sites sampled in 1989 – 2011

Figure 2 showed that the regression relationship of the industrial wastewater with benthic macroinvertebrates tended to separate the more turbid sites (TV1, TV2, TV3 and TV4) with lower richness and values of the bio- indices from the more stable sites (TV5 and TV6) with higher values of these metrics.

4 CONCLUSION

The period from 1989 to 2015, the analysed results showed that the water quality at site of Vedan and Go Dau Ports was polluted clearly after Vedan Vietnam Enterprise operated one year. Additionally, the wastewater from industrial parks along the left of Thi Vai River have also discharged into this river.

There were 36 species of benthic macroinvertebrates belonging to 5 groups of polychaeta, gastropoda, bivalvia, ophiuroidea, and crustacea, in the studied areas of which polychaeta were dominant in species number. Generally, zooplankton abundance during the monitoring was rather high but its species composition was rather low. The values of zooplankton biodiversity index reflected the mesotrophic condition. The density of benthic macroinvertebrates tended to increase too high or to disappear all in near heavy polluted waters.

The taxonomic richness had significant and strong relationships with the water quality variables of DO and total nitrogen. It showed that the regression relationship of the industrial wastewater with benthic

macroinvertebrates tended to separate the more turbid sites (TV1, TV2, TV3 and TV4) with the more stable sites (TV5 and TV6).

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