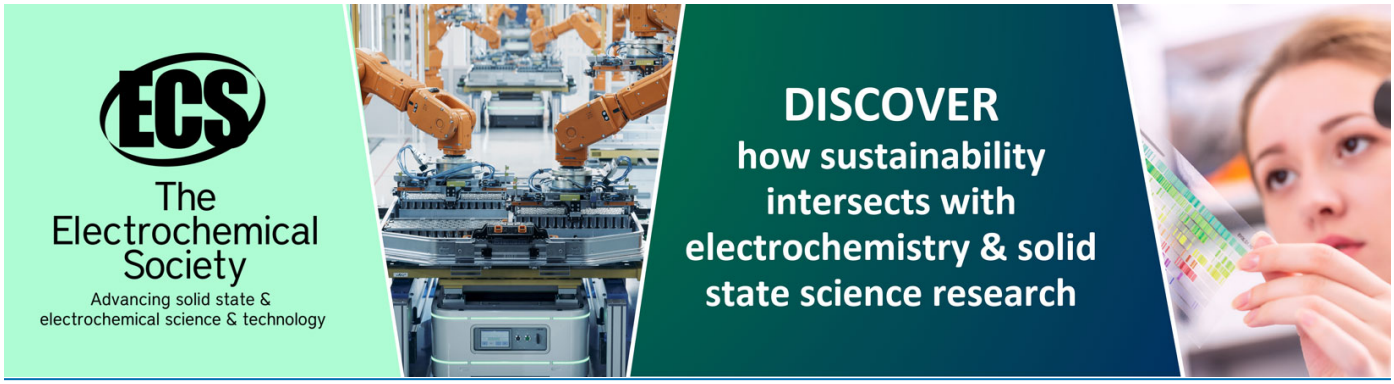
Linking Benthic Macroinvertebrates and Physicochemical Variables for Water Quality Assessment in Saigon River and Its Tributaries, Vietnam



Linking Benthic Macroinvertebrates and Physicochemical Variables for Water Quality Assessment in Saigon River and Its Tributaries, Vietnam

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Abstract. The benthic macroinvertebrates living on the bottom channels are one of the most promising of the potential indicators of river health for the Saigon River and its tributaries with hydrochemistry playing a supporting role. An evaluation of the interrelationships within this approach deems necessary. This work identified and tested these relationships to improve the method for water quality assessment. Data from over 4,500 km^2 watershed were used as a representative example for the Saigon River and its tributaries. The data covered the period March and September, 2007, 2008, 2009, 2010 and 2015. To implement this evaluation, the analyses were based on accepted the methodology of Mekong River Commission and the studies of scientific group for the biological status assessment. For correlation analyses, the selected environmental variables were compared with the ecological indices, based on benthic macroinvertebrates. The results showed that the metrics of Species Richness, H', and 1-D_S had significant and strong relationships with the water quality variables of DO, BOD_5, T_N, and T_P (R^2 = 0.3751 – 0.8866; P << 0.05). While the metrics of Abundance of benthic macroinvertebrates did not have a statistically significant relationship with any water quality variables (R^2 = 0.0000 – 0.0744; P > 0.05). Additionally, the metrics of Species Richness, H', and 1-D_S had negatively correlated with the pH and TSS. Both univariate and multivariate analyses were used to examine the ecological quality of the Saigon River and its tributaries using benthic macroinvertebrates seems to be the most sensitive indicator to correlate with physicochemical variables. This demonstrated that it could be applied to describe the water quality in the Saigon River and its tributaries.

1. Introduction

The Saigon River is a river located in southern Vietnam that rises near Phum Daung in Southwestern Cambodia, flows South and South-Southeast for about 280 kilometers and empties into the Nhabe River, which its turn empties into the East Sea some 20 kilometers North-east of the Mekong Delta. The Saigon River is joined 29 kilometers Northeast of Ho Chi Minh City by the Dongnai River [1]. The Saigon River is very important to Ho Chi Minh City as it is a one of the main water supply as well as the host Saigon Port. The policies for socio-economic development and land-use change have impulsed the economic growth of Tay Ninh, Binh Phuoc, Binh Duong, and Ho Chi Minh City, but the water pollution have a tendency to increase. These consequences of environmental pollution are thus far from inevitable [2]. The high contents of organic pollutants degrade the water quality in receiving waters and threaten the aquatic ecosystems. In addition, the statistics show that the water sources has been, and continued to be, exploited speedily [3].

In order to contribute the water resources management and improve the water quality monitoring for the Saigon River and its tributaries, besides the physiochemical measurements, the aquatic organisms for the ecological health monitoring has been applied more and more because of many their advantages. In Vietnam, up to now, the application of these organisms is rather limited and not verified, especially, the relationships between benthic macroinvertebrates and physicochemical variables for the water quality evaluation [2,4].

According to this approach, the program "*Linking benthic macroinvertebrates and physicochemical variables for water quality assessment in Saigon River its tributaries, Vietnam*" will support for researchers and managers in field of ecology, resources and environment, who can applied these studies for the ecological health monitoring in the Saigon River and its tributaries. The overall objectives of the research were to: (1) Study on the relationships between benthic macroinvertebrates and physicochemical variables for the water quality assessment in the Saigon River and its tributaries; and, (2) Improve the biomonitoring method that serves for the water resources management and the environmental protection in the Saigon River and its tributaries.

2. Materials and methods

2.1. Study sites and sample collection

In the Saigon River and its tributaries, samples of qualitative and quantitative benthic macroinvertebrates, and water quality at 10 sites were collected in March and September 2007, 2008, 2009, 2010 and 2015 (see figure 1) [5].

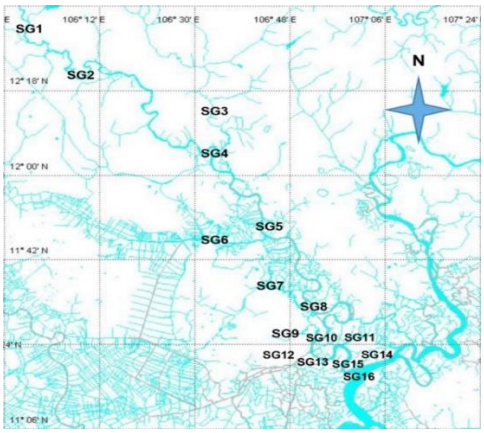


Figure 1. Map of sampling sites.

For benthic macro invertebrates, sample locations 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 [2]. At each sampling location, a composite of four grabs was taken with a Petersen grab sampler, covering a total area of 0.1 m^2. 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. The composite sample was washed through a sieve (0.3 mm) with care taken to be sure 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 [2], [5]. All individuals collected were identified and counted under a compound microscope (with magnifications of 40 – 1200x) or a dissecting microscope (16 – 56x). Oligochaeta, Polychaeta, Gastropoda, Bivalvia, Ophiuroidea, and Crustacea were generally identified to species level. Insecta and Insecta larvae were classified only to genus level. The results were recorded on data sheets and specimens are kept at the Ton Duc Thang University, HCMC, Vietnam.

For water quality, the samples for environmental quality analysis in the field were collected according to the Operational Guide (3rd Ed.), UN Environment Programme (1992) [6]. The samples were taken in March and September of 2007, 2008, 2009, 2010, and 2015. 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 2^0C temperature [6].

2.2. Physical, chemical and benthic macroinvertebrate analysis

The identification of benthic macroinvertebrates was based on morphology and taxonomic books such as Polychaeta [7,8,9,10]; Oligochaeta [11,12]; Gastropoda [12,13,14]; Bivalvia [12,13,14]; Crustacea [12,15,16,17,18,19,20,21]; Insecta [22,23,24,25,26,27].

The aquatic environmental parameters (pH, total suspended solid – TSS, dissolve oxygen – DO, biological oxygen demand – BOD_5, total nitrogen – T_N, and total phosphorus – T_P) were analyzed according to standard methods (APHA-AWWA-WEF, 1998) [28].

2.3. Data analysis

For all sites sampled in April and September 2007, 2008, 2009, 2010 and 2015 the following metrics were calculated (i) taxonomic richness (i.e. number of taxa); (ii) abundance (i.e. numbers of individuals per site); (iii) the Shannon-Wiener Diversity Index [29]; and, (iv) the Simpson Density Index [30]. The Pearson test (SPSS, version 16.0) was used for calculation on the correlation between benthic macroinvertebrates species number, abundance and biodiversity index) and environmental parameters in the Saigon River and its tributaries. The three metrics were tested for their potential as indicators of human impact by regressing values for two seasons of 2007, 2008, 2009, 2010 and 2015 (160 sampling events for 16 sites) against the water quality variables (pH, TSS, DO, BOD_5, T_N and T_P). For each metric examined against these variables, p values and r^2 values were calculated from regression analyses.

3. Research results

3.1. General characteristics of benthic macroinvertebrates

During the ten monitoring times, there were 49 taxa of benthic macroinvertebrates belonging to 6 groups of polychaetes, oligochaetes, gastropods, bivalves, ophiuroids, crustaceans, and insects. None organisms were dominant in the benthic macroinvertebrates communities. In each monitoring, species number of benthic macroinvertebrates ranged from 29 (March 2008) to 38 (September 2015) taxa.

The insects were the most species-rich group and occurred in almost sites. In addition, polychaets, oligochaetes, gastropods, bivalves and crustaceans also occurred widely in the studied areas. Taxon richness at a site ranged widely at the 16 sites sampled in March and September, 2007, 2008, 2009, 2010, and 2015. Richness ranged from 0 (a few canals inside of HCMC) to 15 (upper sites of Saigon River) taxa. The species of benthic macroinvertebrates recorded in the Saigon River and its tributaries were originated from the estuary or coastal region, including all polychaetes; *Melita* sp., *Grandidierella lignorum, Tachaea* sp., *Cyathura truncata, Apseudes vietnamensis, Alpheus bisincisus, Alpheus* sp. (Crustacea). A number of the species that were polluted tolerance such as *Nephthys polybranchia, Polydora* sp., *Eudistylia polymorpha* (Polychaeta); *Branchiodirus semperi, Limnodrilus hoffmeisteri, Branchiura sowerbyi* (Oligochaeta); *Melanoides tuberculatus* (Gastropoda); *Chironomus* sp., *Cryptochironomus* sp. (Insecta). While, there were few species these were sensitive, including *Neanthes meggitti* (Polychaeta), *Dromogomphus* sp., *Macronema* sp., *Hydropsyche* sp. (Insecta).

The number of individuals at sites was highly variable, ranging from 0 to 6,550 individuals/sample. The density of benthic macroinvertebrates tended to increase too high or to disappear all in near big cities or industrial areas. The oligochaete species of *Limnodrilus hoffmeisteri* was dominant in almost sites in the monitored area.

3.2. Bioindex analysis

The values of bio-indices for the water quality assessment for the Saigon River and its tributaries were presented in table 1.

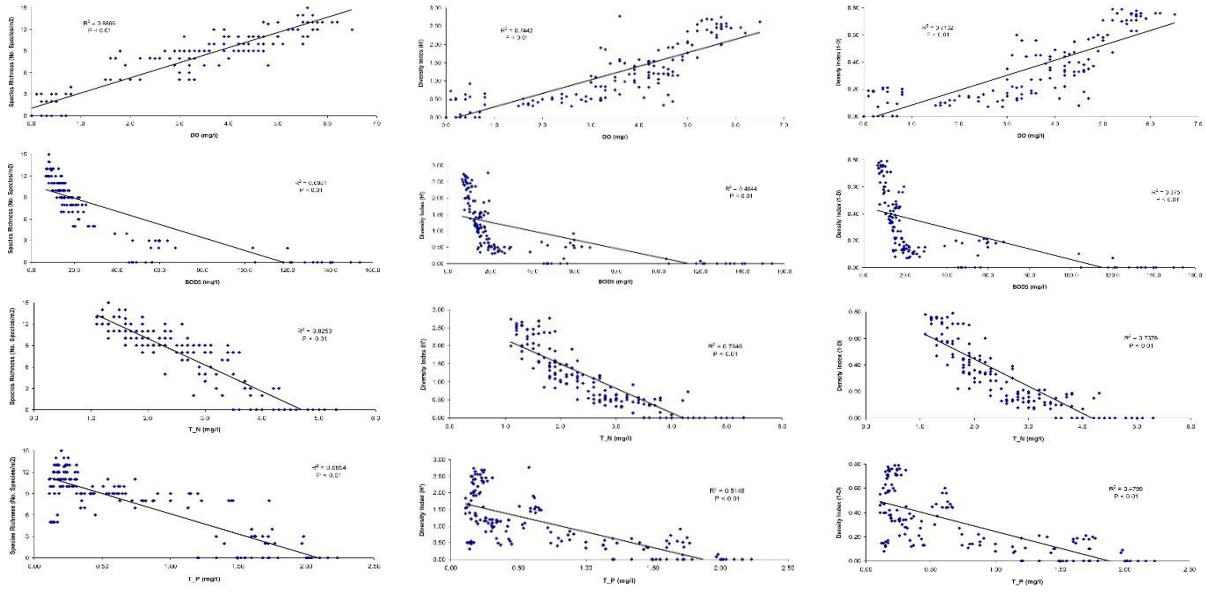
3.3. Relationships of Benthic Macroinvertebrates and Physicochemical Variables

The metrics of Species Richness, H', and 1-D_S had significant and strong relationships with the water quality variables of DO, BOD_5, T_N, and T_P (R^2 = 0.3751 – 0.8866; P << 0.05) (figures 2 a, b, c).

Table 1. Bio-Indices of Benthic Macroinvertebrates for Water Quality Assessment in the Saigon River and its tributaries in March and September, 2007, 2008, 2009, 2010, and 2015.

Sites	H'	1-D_S	Ranking [2]
SG1	2.40 – 3.01	0.70 – 0.84	Light pollution
SG2	1.64 – 2.32	0.47 – 0.68	Light pollution – Low moderate pollution
SG3	1.21 – 1.54	0.40 – 0.46	Low moderate pollution
SG4	1.08 – 1.31	0.33 – 0.36	Low moderate pollution – High moderate pollution
SG5	0.83 – 1.09	0.21 – 0.30	High moderate pollution
SG6	0.32 – 0.51	0.08 – 0.15	Heavy pollution
SG7	0	0	Very heavy pollution
SG8	0.49 – 1.18	0.12 – 0.39	High moderate pollution – Heavy pollution
SG9	0	0	Heavy pollution
SG10	0.32 – 0.42	0.08 – 0.12	Heavy pollution
SG11	0.41 – 0.64	0.11 – 0.16	Heavy pollution
SG12	0	0	Heavy pollution – Very heavy pollution
SG13	0.48 – 0.72	0.15 – 0.19	Heavy pollution
SG14	0.85 – 1.59	0.22 – 0.45	High moderate pollution
SG15	1.48 – 2.77	0.44 – 0.84	Low moderate pollution
SG16	2.19 – 2.55	0.63 – 0.79	Light pollution

Notes: H' (Shannon-Wiener Diversity Index), and D_S (Simpson Dominance Index).



(a) **(b)** **(c)**

Figure 2. Relationships between the metrics of Species Richness (a); H' (b); and, 1-D (c) with the water quality variables for sites sampled in March and September, 2007, 2008, 2009, 2010, and 2015.

4. Conclusion

During the ten monitoring times in 2007, 2008, 2009, 2010 and 2015 at Saigon River and its tributaries, there were 49 taxa of benthic macroinvertebrates belonging to 6 groups of polychaetes, oligochaetes, gastropods, bivalves, ophiuroids, crustaceans, and insects, in the studied areas of which none organisms were dominant in the benthic macroinvertebrates communities. Generally, the changes

of abundance and dominant species at 16 sites expressed clearly the environmental characteristics of the Saigon River and its tributaries, and the number of individuals tended to increase in urban and industrial sites, where more organic pollution. The bio-index values tended to decrease in the urban and industrial sites with high turbidity. These results were suitable for the analysis of benthic macroinvertebrates communities. The metrics of Species Richness, H', and $1\text{-}D_S$ had significant and strong relationships with the water quality variables of DO, BOD_5, T_N, and T_P. The metrics of Abundance of benthic macroinvertebrates did not have a statistically significant relationship with any water quality variables. Additionally, the metrics of Species Richness, H', and $1\text{-}D_S$ had negatively correlated with pH and TSS. Results of this study contributed the interesting information on benthic macroinvertebrates structure, their correlation with environmental parameters and ecological characteristics, which was quite limited in Saigon River and its tributaries. Besides, the results confirmed the advantage of using benthic macroinvertebrates and their indices as useful tools for environmental monitoring and ecological health assessment.

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