PROJECT
"INTEGRATED MANAGEMENT OF
LAGOON ACTIVITIES IN THUA THIEN HUE PROVINCE"
(IMOLA PROJECT)

Integrated Management of Lagoon Activities in Thua Thien Hue Province

ASSESSMENT OF WATER AND SEDIMENT QUALITY OF TAM GIANG – CAU HAI LAGOON 2006 - 2007

(Belonging to Natural Resources Unit)

Hue - February, 2008

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Implement Group

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1. INTRODUCTION

Tam Giang - Cau Hai lagoon system in Thua Thien Hue province is a typical coastal brackish water body. It is one of the biggest lagoons in Southeast Asia stretching about 70 km from the estuary of O Lau river to Cau Hai lagoon. It has an area of 22,000 ha with the largest cross section of over 1 km, the narrowest part of about 0.5 km, and average depth of 1.5 m. Tam Giang-Cau Hai lagoon joins the sea by Thuan An and Tu Hien inlets and receives fresh water from most rivers such as Huong, Bo, O Lau, Dai Giang, and Truoi. The tidal regime of this lagoon is semi-diurnal tide. Tam Giang-Cau Hai lagoon system plays a very important role in the water regulation, preventing salinity intrusion, the transportation on waterway and in the exploitation and production of aquatic products. In general, its brackish habitat is an advance of distribution and development of the diversity of aquatic organism, which have made a great profit on the aquatic products for about 300,000 inhabitant living in the region [20].

Since the historic flood in 1999, the increase of the lagoon salinity caused by the formation of a new mouth Hoa Duan (filled up in 2000) and the expansion of Tu Hien mouth has promoted brackish water aquaculture development, especially shrimp culture, increased from 2,000 ha (in 2000) to 3,700 ha (in 2003). It is estimated that the aquaculture pond area will be up to 7,000 ha in 2010. However, the rapidly increase of shrimp culture in the region, especially inside the lagoon and the uncontrolled exploitation of natural aquatic resources has polluted the lagoon and exhausted the natural resources of Tam Giang - Cau Hai lagoon [21].

In recent years, there have been researches and projects studying on the lagoon environment and natural resources, such as the Project “Research on the sustainable development of Thua Thien Hue lagoon” (1998-2003) supported by Nord Pas de Calais Region (NPC) [38] and “The Integrated Coastal Zone Management (ICZM, 2001-2005) supported by Netherlands [8]... These projects mainly focused on water environment and biodiversity assessment of Huong river and Tam Giang-Cau Hai lagoon. However, there are still some problems which have not been elucidated such as water pollution sources, impacts of water and sediment quality on the lagoon ecosystem, and especially eutrophic status of the lagoon - a potential danger to the deterioration of the lagoon ecosystem.

The recognition of coastal eutrophication as a global problem is relatively recent (Nixon, 1995) and it is attracting the increasing attention from the scientific community [30]. Eutrophication, indeed, is one of the most frequent and widely spread phenomena associated with human utilization of coastal oceans [5]. Studies on the assessment of marine eutrophication have been historically based on chemical measurements (e.g. inorganic nitrogen and phosphorus) and/or surrogate measurements of algal biomass (i.e. N, P and chlorophyll-a concentrations) [35], but eutrophication induce responses at different hierarchic levels of the ecosystem organization. Responses have been so far detected at the community level in terms of primary producers community composition (e.g. from perennial macroalgae and sea-grasses, to ephemeral macroalgae, to pelagic microalgae) [23], of community size spectra [16] and of biodiversity shifts [12,33].

Other approaches integrated different variables in order to define synthetic trophic state indices based on the analysis of predictive or responsive variables of algal growth, such as inorganic phosphorus, chlorophyll-a concentrations and water column turbidity. These cascade effects, however, are far from representing a general rule. In fact, predictive (i.e. nutrient concentrations) and responsive variables (e.g. algal biomass measured as chlorophyll a) are not always effective. For example, in nutrient-enriched systems (lagoons, ponds, and estuaries) the fluctuations in the concentration of suspended chlorophyll-a are often due to the microphytobenthos resuspension rather than to increased nutrient levels and the consequent is increased algal growth [6,25]. Moreover, the use of chlorophyll-a content as a proxy of algal biomass is questionable as chlorophyll content per cell may change from species to species and within the same species it displays daily variations depending on environmental and physiological conditions [39].

The progressive accumulation of results disconfirming the view of eutrophication as a cascade of effects derived from enhanced nutrient availability has stimulated new conceptual models for the assessment of this process. Nixon (1995) proposed a new approach for the assessment of the trophic state of marine systems based on the supply of total organic C to the system (as g C m^{-2} y^{-1}) [30]. This approach tentatively moved the focus on the potential consequences of eutrophication on benthic systems, but, without taking into consideration the mechanisms of removal/export of organic C within sediments, it still appears to have a poor sensitivity. Moreover, the complex hydrodynamic forcing operating at shallow depths in coastal systems might lead to discrepancies between the assessments of trophic conditions based on water column vs. those based on sediment variables [11]. Therefore, it appears that there is a strong need of identifying new descriptors of the trophic state of marine coastal systems, able of taking into account all the components potentially affected by eutrophication, thus including the benthic environment.

The Natural Resources Unit of the FAO-"Integrated Management of Lagoon Activities in Thua Thien Hue Province" Project included among its first activities, an environment survey, in order to obtain an overview of water quality and sediment resources, using Geographical Information System (GIS); to implement a Hydro-biological model and setup some new tools like trophic and ecosystem health indicator, usefully for the monitoring activity in future, and develop an environmental database integrated with all available past dataset.

The main objectives of this study (accepted in the LOA between FAO and Hue College of Sciences in the fiscal year of 2006 and 2007, belonging to "Integrated Management of Lagoon Activities in Thua Thien Hue Province" project) are:

- Definition of tools and key parameters for future environmental monitoring programs;
- Application of new signatures of benthic eutrophication based on the analysis of the quantity, biochemical composition and origin of sediment organic matter;
- Discovery of potential pollutants in the water and sediment and designing environmental monitoring stations and program for the future.

2. METHODOLOGY

2.1. Sampling

2.1.1. Sampling sites

Figure 1 and *Table 1* show the sampling sites in Tam Giang – Cau Hai lagoon, including 12 stations/cross-sections (marked from A to L) stretching from the North to South of the lagoon, in which 37 sites were in the inside of lagoon (3 – 4 sites in a cross-section) and 8 sites in the canals adjacent to aquaculture ponds (5 sites in Quang

An commune and 3 sites in Sam-An Truyen area (belonging to Thuy Tu region). The water samples taken in the canals were named CAA1 – CAA5 (for Sam-An Truyen) and CAA6 – CAA8 (for Quang An).

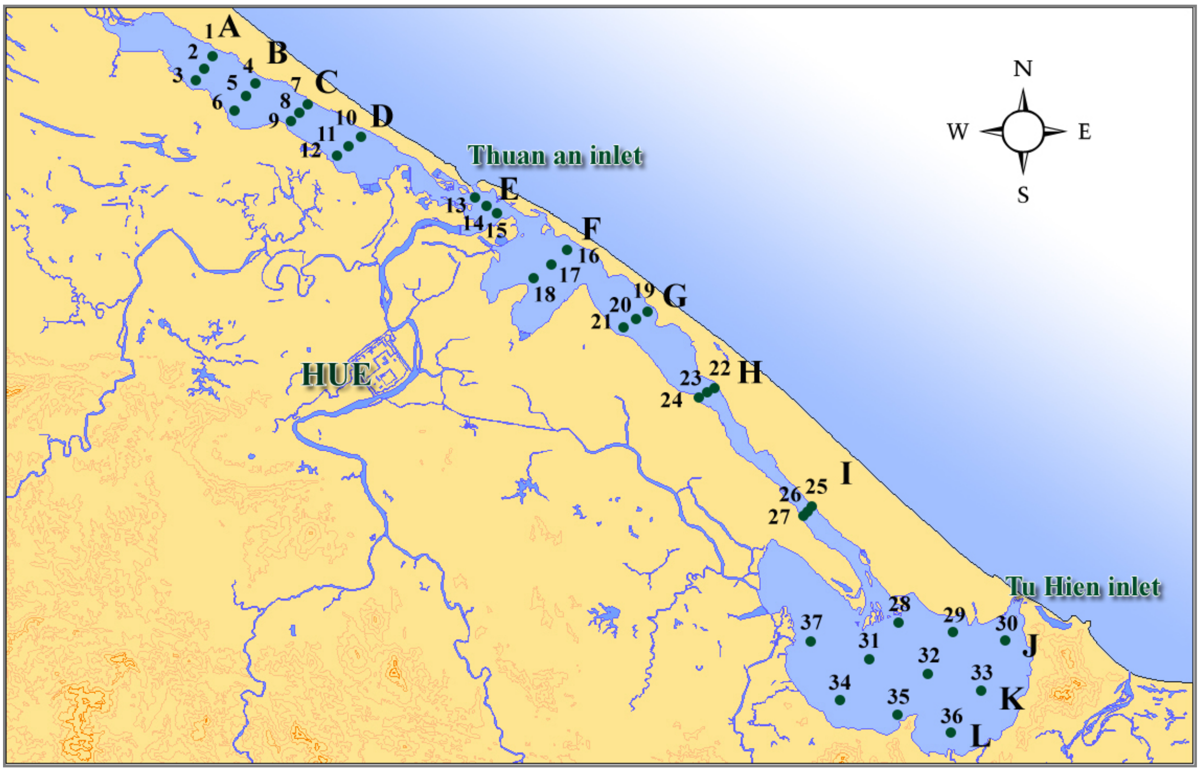

Figure1. *Map of sampling sites and stations in Tam Giang – Cau Hai lagoon*

Table 1. *Symbol of monitoring sites and their co-ordinates*

Area	***Sites***	***Co-ordinate***	
		Latitude	*Longitude*
	A01	16°39'150	107°26'475
	A02	16°38'738	107°26'367
	A03	16°38'400	107°26'248
	B04	16°37'977	107°29'652
	B05	16°37'628	107°29'317
	B06	16°37'175	107°29'077
	C07	16°36'782	107°31'547
Tam Giang	C08	16°36'667	107°31'492
	C09	16°36'473	107°31'418
	D10	16°36'688	107°33'965
	D11	16°35'322	107°33'680
	D12	16°35'015	107°33'392
	E13	16°33'887	107°37'360
	E14	16°33'552	107°37'800
	E15	16°33'173	107°38'238
Thuy Tu	F16	16°32'080	107°40'844
	F17	16°31'713	107°40'500
	F18	16°31'085	107°40'107

Area	*Sites*	*Co-ordinate*	
		Latitude	*Longitude*
	G19	16°29'658	107°43'461
	G20	16°29'325	107°43'273
	G21	16°29'205	107°42'967
	H22	16°26'450	107°46'058
	H23	16°26'318	107°45'822
	H24	16°26'250	107°45'694
	I25	16°23'990	107°48'378
	I26	16°23'743	107°48'303
	I27	16°23'515	107°48'298
Cau Hai	J28	16°20'412	107°51'293
	J29	16°20'490	107°53'102
	J30	16°20'758	107°54'757
	K31	16°19'558	107°50'430
	K32	16°19'155	107°52'123
	K33	16°18'750	107°53'830
	K34	16°20'115	107°48'822
	L35	16°18'162	107°49'736
	L36	16°17'905	107°51'102
	L37	16°17'243	107°52'710
Sam – An Truyen	CAA1	16°31'703	107°38'708
	CAA2	16°30'848	107°37'985
	CAA3	16°30'312	107°38'863
	CAA4	16°30'583	107°40'067
	CAA5	16°31'270	107°39'386
Quang An	CAA6	16°34'529	107°33'300
	CAA7	16°34'189	107°34'150
	CAA8	16°34'268	107°34'318

2.1.2. Sampling frequency and sampling

– Sampling frequency: 5 sessions in April, May, August, and November of 2006 and May of 2007.

– Sampling procedure:

+ Water sample:

- Surface water samples were composite ones with the ratio of 1 to 1 of the parts taken at two depths of water column (50 and 100 cm).
- Water samples in the channel adjacent to aquaculture ponds were also composite ones from the parts taken at three sampling points with the depth of 30 cm.

+ Sediment sample: taken at the depth of 0 – 10 cm.

– Sampling equipments: Water sampler (Wildco type) for the water sampling and dredge (Peterson type) for the sediment sampling.

2.1.3. Quantity of sample, analysis parameters and sample storage

Quantity of sample, analysis parameters and sample storage are showed in *Table 2*. Some water quality parameters were measured at field and others were analyzed in laboratory. Sediment quality parameters were determined in laboratory. All water and sediment samples were stored according to the guidelines in Vietnam standards and/or Standard Methods for Examination of Water and Wastewater (SMEWW, 1998) [3].

Table 2*. Quantity of sample, analysis parameters in one sampling session and sample storage*

Sample	Quantity	Analysis parameter	Storage condition
Water	45[(a)]	- Temperature, pH, Turbidity (TUR), Transparency, Salinity (SAL), Dissolved Oxygen (DO)	Measured at field
		- Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Suspended Solid (SS), NO_2-N, NO_3-N, PO_4-P, ammonia-N, Total Nitrogen (TN), Total Phosphorus (TP), Chlorophyll-a, Photosynthesis Pigment, Total Coliforms (TC), and Fecal Coliform (FC).	At 4^oC in PET bottles for physical and chemical parameters; at 4^oC in sterilized glass bottles for bacterial analysis
	12 [(b)]	Organochlorine Pesticides – OCs (DDTs and HCHs), and Heavy Metals (Cu^{II}, Pb^{II}, Zn^{II}, and Cd^{II}).	In dark glass bottles at 4^oC for OCs analysis; samples for analysis of heavy metals were acidified (pH = 2) with concentrated nitric acid and stored in PET bottles.
Sediment	37	Chlorophyll-a, photosynthesis pigment (PSP), total organic matters (TOM), total lipids (TLIP), total proteins (TPRO), and total carbohydrates (TCAR).	At -20^oC in deep freezer
	12 [(b)]	Organochlorine pesticides – OCs (DDTs and HCHs) and heavy metals (Cu^{II}, Pb^{II}, Zn^{II}, and Cd^{II}).	At -20^oC in deep freezer

[(a)] The 45 samples included 37 samples inside the lagoon and 8 samples in canals adjacent to aquaculture ponds.

[(b)] These samples were composite ones collected from 3 sample portions taken at each site.

2.2. Analysis methods

In this study, the used analysis methods are the standard methods of Vietnam and/or SMEWW (APHA, 1998) . Some procedure was modified to fit the laboratorial condition. The parameters which is used to assess water and sediment quality and their analysis methods are presented in *Table 3*.

***Table 3**. Analysis methods, water and sediment quality parameters*

N^o	Parameters	Methods$^{(*)}$	Description
1	Temperature	Thermometer	-
2	pH	pH-meter	Potentometry using glass electrode
3	DO	DO-meter	Voltammetric measurement
4	EC (electric conductivity)	Conductivity meter	-
5	Salinity (SAL)	Electrical conductivity (SMEWW-2520 B)	Based on empirical relationship between salinity, conductivity and temperature.
6	Turbidity (TUR)	Turbidity meter	Nephelometric method
7	Suspended Solids (SS)	Gravimetry (SMEWW-2540 D)	Sample is filtered through a weighed 0.45µm glass-fiber filter and the residue retained on the filter is dried to constant weigh at 103 – 105^{o}C. The increase in weight of the filter represents the SS.
8	BOD_5	Ultimate BOD Test (SMEWW-5210 C)	300-mL airtight bottle is filled with sample and incubated under 20^{o}C condition. Dissolved oxygen (DO) is measured initially and after incubation within 5 day by DO-meter.
9	COD	Dichromate Closed Reflux Colorimetry (SMEWW-5220 D)	Oxidizing organic matter by mixture of chromic and sulfuric acid in closed cuvets under 150^{o}C for 2 hours; measuring the absorbance at 420 nm.
10	Chlorophyll-a and photosynthesis pigment	Spectrophotometry (Water samples: SMEWW-10200 H; Sediment samples: [10,24]	- For water sample (SMEWW-10200 H): filter water sample through a pre-washed 47mm glass fiber filter. Chlorophyll-a and phaeophytin concentrations in the extract are determined spectrophotometrically at 750 nm and 664 nm before acidification,

Nº	Parameters	Methods(*)	Description
			and 750 nm and 665 nm after acidification. - For sediment sample (Plante-Cuny, 1974): Extract chlorophyll-a and phaeophytin from wet or frozen sediment by using ultrasound bath in ice, at 50-100 W for 3 min, with 30 sec of interval between each minute of sonication. The determination of chlorophyll-a and phaeophytin concentrations is similar to water sample.
11	Phosphate (PO4) and Total phosphorous (TP)	Spectrophotometry, Ascorbic acid method (SMEWW-4500-P E and 4500-P B)	• PO4-P: Phosphorus molybdic heteropolymeric acid is produced by the reaction of ammonium molybdate and potassium antimonium tartrate with ortho phosphate of sample. Reducing this acid to green molybden by ascorbic acid. Measuring optical density at 880 nm. • TP: All of phosphorus species was converted to ortho phosphate by persulphate under acidic medium. The sample digestion is carried out in autoclave at 120^{o}C for 30 min.
12	Nitrite (NO_2-N)	Colorimetry (SMEWW- 4500 - NO_2^- B)	Making reddish purple azo dye by mixing sulphanilic acid, α-napthylamine with specific amount of sample at pH 2.0 to 2.5; measuring optical density of azo at 543 nm and making equivalent to concentration of nitrite
13	Nitrate (NO_3-N) and Total Nitrogen (TN)	Cadmium Reduction (SMEWW-4500-NO_3^- E)	• NO_3-N: Reduce all of NO_3^- to NO_2^- by cadmium. • TN: All of nitrogen species was converted to NO_3^- by persulphate under base medium. The sample digestion is carried out in autoclave at 120^{o}C for 30 min.
14	Ammonia (NH_4-N)	Phenate (SMEWW-4500-NH_3 F)	Green indophenol was produced by reaction of ammonia, hypochlorite ion and phenol; measuring optical density of indophenol at 640 nm and making

Nº	Parameters	Methods(*)	Description
			equivalent to concentration of ammonia
15	Total Coliform (TC) and Fecal Coliform (FC)	Most Probable Number (MPN) (SMEWW-9221)	• TC: Apply multiple-tube fermentation technique; dilute sample in a series of 3 dilution level in Lauryl Sulphate Broth medium; incubate at 37±1^{o}C for 48 hours; transfer positive tubes to the Brilliant Green Lactose Bile Salt medium and incubate at 37±1^{o}C for 48 hours. • FC: transfer positive tubes detected from TC to EMB agar medium; incubate at 37±1^{o}C for 24 hours; transfer to Trypton medium and incubate 44.5±1^{o}C within 24 hours; determine positive tubes (red color) after adding Kovac's reagent. Calculate and record TC or FC in terms of the Most Probable Number (MPN) using the appropriate statistic tables.
16	Total Organic Matter	Gravimetry	Determine the loss of weight after calcinations of dried sediment sample in a muffle furnace at 450°C for 2 hours.
17	Total Protein	Colorimetry [15,19,34]	Disperse protein of sediment into water by using ultrasound. Under alkaline conditions (pH = 10) the divalent copper ion forms a complex with peptide bonds in which it is reduced to a monovalent ion. Monovalent copper ion and the radical groups of tyrosine, tryptophan, and cysteine react with Folin and Ciocalteu reagent to produce an unstable product that becomes reduced to molybdenum/tungsten blue. The absorbance is determined at 650 nm. The calibration curve is prepared using bovine serum albumin (BSA) as standards.
18	Total Carbohydrate	Phenol-sulfuric acid [13]	The reaction of carbohydrate and phenol in the present of concentrated sulfuric acid produces a light yellow color. The absorbance is determined at 485 and 600

N^o	Parameters	Methods$^{(*)}$	Description
			nm. The absorbance at 600 nm is an estimate of the turbidity of the supernatant. Using D(+)-Glucose as standards.
19	Total Lipid	Colorimetry [27]	Separate lipid mixtures from sediment through the solvent extraction technique using the chloroform-methanol solvent. The reaction of extracted dry lipid and concentrated sulfuric acid is carried out at 180 – 200^{o}C for 15 min in a dry hot bath. After specific cooling protocol, the absorbance is measure at 375 nm. Lipid concentration is calculated from calibration curves of standard solutions of tripalmitine.
20	Biopolymeric Carbon	[14,32]	– Protein, carbohydrate and lipid concentrations were converted to carbon equivalents by using the following conversion factors: 0.49, 0.40 and 0.75 μg of C μg^{-1}, respectively – The sum of protein, carbohydrate and lipid carbon was referred as biopolymeric carbon.
21	Organochlorine pesticides (OCs: DDTs and HCHs)	Gas chromatography with electron capture detector (GC/ECD)	1. Extraction of OCs from sample (2 L of water or 10 g of sediment) is made by appropriate technique: – *Water samples* are extracted at neutral pH with n-hexane, using separator funnel technique. – *Sediment samples* are extracted with n-hexane, using Soxhlet technique. The sediment sample is mixed with anhydrous sodium sulfate, placed in an extraction thimble, and extracted with n-hexane in a Soxhlet extractor. The extract is then concentrated by purging with nitrogen before the next cleanup step. 2. The concentrated extract is put into florisil column. After that, OCs are eluted

N°	Parameters	Methods(*)	Description
			from the column by n-hexane. The eluted faction is concentrated by purging with nitrogen prior to gas chromatographic analysis. 3. 01-μL sample is injected into the capillary column for GC/ECD analysis under appropriate conditions. Calibration curve method is used for quantitation of OCs.
22	Heavy metal (Cu, Pb, Zn, Cd)	Differential pulse anodic stripping voltammetry (DP-ASV) on hanging mercury drop electrode (HMDE)	• *Sample decomposition*: water samples are boiled in acid mixture to decompose organic matters before analysis. Sediment samples are digested in acid mixture and then filtered before analysis. • Procedure for Cu^{II}, Pb^{II}, Zn^{II}, Cd^{II} determination by DP- ASV on HMDE: + The metals are deposited on the HMDE by electrolyzing at the potential of -1000 mV (vs. Ag/AgCl) for 120 s in acetate buffer (pH = 4.5). During this time, analytical solution is stirred by magnetic stirrer coated with teflon at a constant speed. After the deposition step, the stirring is stopped and the solution is remained quite for 30 s. + After that, stripping step is carried out by scanning potential in anodic direction from -1000 mV to -100 mV. Stripping voltammograms are recorded by differential pulse voltammetry. - The metal concentration is determined by standard addition method.

(*) *SMEWW - Standard Methods for Examination of Water and Wastewater*

2.3. Quality control (QC)

– The accuracy of the above methods was checked by analysis of spiked samples.

– The precision of the methods were checked by replicated analysis.

– Blank values were always determined at the same time for the trace analysis (heavy metals and OCs).

2.4. Guidelines/standards used for water and sediment quality assessment

– Assessment of water quality in the lagoon and aquaculture areas was based on Vietnam Standards TCVN 5943-1995 issued by Ministry of Natural Resources and Environment for the quality of coastal marine water used for aquaculture [28] and Vietnam Standards 28 TCVN 171-2001 issued by Ministry of Fisheries for black tiger shrimp culture [29].

– Assessment of sediment quality in the terms of toxic chemicals (toxic metals and OCs – DDTs, HCHs) was based on Canadian Environment Quality Guidelines (EQGs, 2002) [2].

3. RESULTS AND DISCUSSION

Raw data of water and sediment quality observed at the monitoring stations and the canals adjacent to aquaculture ponds in Tam Giang – Cau Hai Lagoon during the investigated period (2006 - 2007) are showed in appendices.

3.1. Water quality of Tam Giang – Cau Hai lagoon in 2006 and 2007

Generally, most of water quality parameters of Tam Giang – Cau Hai (TG – CH) such as temperature, pH, DO, BOD_5, ammonia (NH_4/NH_3), heavy metals (Cu, Pb, Cd and Zn) met the requirement of the Vietnam Standard (TCVN 5943-1995) for the coastal water quality which is used for aquaculture and other purposes (*Table 4*). The anxious problems of the lagoon water quality were organic pollution (high COD concentration), bacteria pollution (high total coliform and fecal coliform concentration) and level of nutrients (nitrogen and phosphorus) potential to eutrophication.

3.1.1. Temperature

Water temperature changed with the season and day time. According to NPC (1998 – 2003), the variation of water temperature in TG – CH lagoon was in the range of 15 – 35^oC, the difference of temperature between the rainy and dry season was from 2 to 8^oC. Particularly, there was a reverse stratification of water temperature (temperature in the surface lower than that in the bottom layer) in the south of at Cau Hai area with the differences up to 6 – 7^oC.

During the study period, the temperature of the lagoon water was in the range of 23 – 34°C with the mean of 26 – 31°C. Especialy, there was a local high-temperarture phenomenon in the south of Cau Hai area with water temperature up to 32 – 34°C. The water temperature variation was insignificant in Thuy Tu area (stations from E to J).

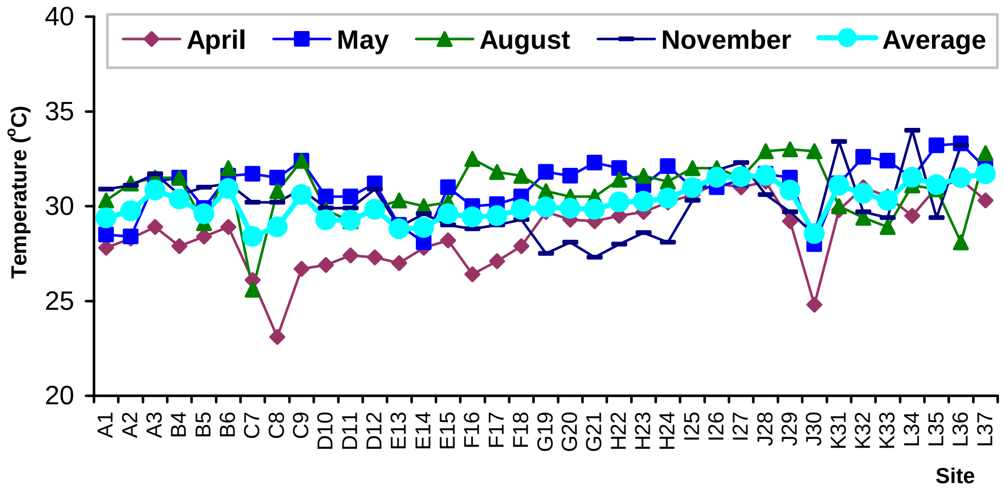

Figure 2. *The spatial and temporal variation of water temperature in Tam Giang-Cau Hai lagoon*

3.1.2. pH

The pH value of the lagoon water was affected by many factors such as season, tidal regime, inflow from rivers... In the dry season , due to effect of the tide via two inlets Thuan An and Tu Hien, the pH was usualy higher than that in the rainy season. The pH variation of TG – CH lagoon is showed in *Figure 3*. The results in this study agreed with the report of NPC project (Nord Pas de Calais, 1998 – 2003), the average pH value was in the large range of 6 – 9 [34].

In O Lau estuary area (stations from A to C), the pH value varied significantly with the time of year (pH = 5.5 – 9.0). In other stations (stations from D to L) the pH was relatively stable between 7.5 and 8.5. These levels of pH met the requirement of Vietnamese Standard (TCVN 5943-1995) applied to the coastal marine water (pH = 6.5 – 8.5) used for aquaculture and standard 28 TCN 171:2001 of Ministry of Fisheries applied to the intensive culture of black tiger shrimp (pH = 7.5 – 8.5).

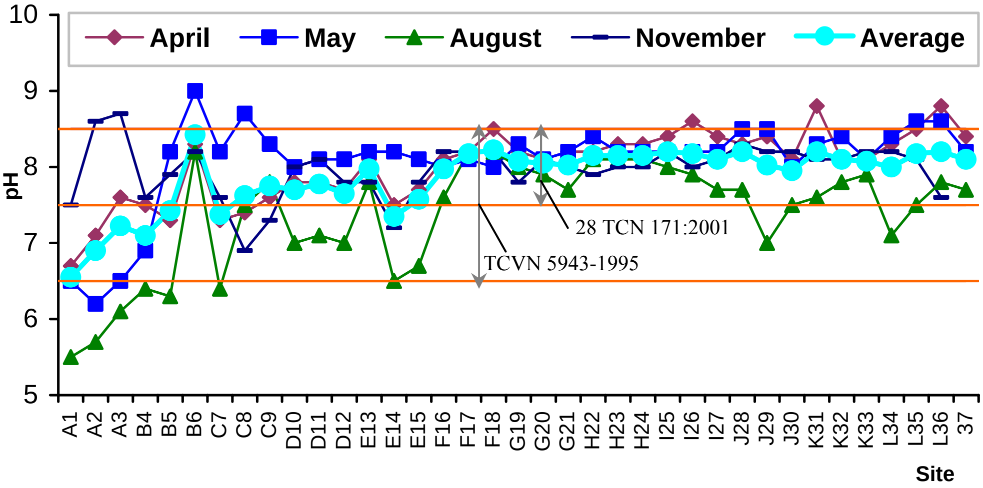

Figure 3. *The spatial and temporal variation of the water pH in TG – CH lagoon*

3.1.3. Salinity

Salinity (SAL) is one of important parameters which influences the other WQ parameters and the biodiversity of TG – CH lagoon. SAL of the lagoon was affected by the factors such as season (dry or rainy season), inflows from rivers Huong, O Lau, Truoi, Cau Hai …, rainfall, and tidal regime… In NPC project report [38] (see *Figure 4*) and ICZM report (ICZM, 2002 – 2003) [8], SAL was commonly high in the dry season (Mar. – Aug.) and low in the rainy season (Sep. – Dec., SAL < 5‰) and in the early dry season (Jan. – Feb., SAL < 10‰). In the middle and the end of dry season, the lagoon SAL was suitable for brackish aquaculture, especially for black tiger shrimp culture. In fact, activities of brackish aquaculture at the lagoon have been developing rapidly in the recent years (see *Figure 5*). It is planned that the culture area will increase up to 7,000 ha in 2010.

Table 4. *Summary of water quality characteristics of Tam Giang – Cau Hai lagoon (4, 5, 8, 11/2006 and 5/2007)*

Nº	Parameters	Unit	Tam Giang		Thuy Tu		Cau Hai		TCVN 5943-1995[d]
			Min – Max	T. bình ± S[a]	Min – Max	T. bình ± S[b]	Min – Max	Mean ± S[c]	
1	Temparature	^oC	23.1–32.4	29.6±1.85	26.4–32.5	30.3±1.60	24.8–34.0	30.9±1.90	–
2	pH		5.50–9.00	7.49±0.77	7.60–8.60	8.12±0.20	7.00–8.80	8.10±0.41	6.5 – 8.5
3	Salinity	$^0/_{00}$	<1.00–31.5	8.22±8.29	4.50–25.0	17.0±5.01	<1.00–34.0	17.7±7.22	–
4	Transparency	cm	40.0–7100	261±1032	30.0–270	148±56.1	50.0–250	148±47.7	–
5	DO	mg/l	5.20–8.30	6.67±0.60	5.50–7.90	6.86±0.58	5.60–9.10	6.80±0.83	≥ 5
6	BOD_5	mg/l	0.5–3	1 ± 0.5	0.5–5	2±1	0.5–6	1± 1	< 10
7	COD	mg/l	1.60–12.3	6.00±2.03	1.70–13.6	5.88±2.18	2.60–21.5	6.21± 2.75	–
8	Chlorophyll-a	µg/l	0.20–9.20	2.59±2.25	0.40–24.8	4.22±4.15	0.30–8.20	2.20±1.62	–
9	Total Coliform	MPN/100ml	0–110000	7327±16633	0–110000	9447±22213	150–750000	47127±137196	1000
10	Fecal Coliform	MPN/100ml	0.00–2800	735±643	0.00–2800	750±693	0–40000	3401±9186	–
11	N-NH4/NH3	mg/l	<0.02–0.10	0.04±0.02	<0.02–0.12	0.04±0.02	<0.02–0.14	0.06± 0.04	0,5
12	N-NO3	mg/l	<0.05–0.26	0.12±0.06	<0.05–0.13	0.07±0.02	<0.05–0.07	0.06±0.01	–
13	P-PO4	mg/l	<0.01–0.10	0.03±0.02	<0.01–0.05	0.02±0.01	<0.01–0.03	0.01±0.01	–
14	TN	mg/l	<0.05–1.88	0.59±0.45	0.06–2.88	1.11±0.60	0.25–3.46	0.92± 0.57	–
15	TP	mg/l	0.40–134	22.4±39.2	0.01–0.09	0.04±0.02	<0.01–0.06	0.03± 0.02	–
16	Cu	µg/l	<0.01–134	22.4±39.3	<0.01–140	21.6±41.6	<0.01–108	29.2± 43.4	10
17	Pb	µg/l	<0.25–3.65	0.65±0.71	0.01–3.68	0.94±0.75	<0.25–7.43	1.83± 2.04	50
18	Cd	µg/l	0.01–6.58	0.39±1.30	0.01–4.89	0.51±1.09	<0.01–9.29	1.48±2.59	5
19	Zn	µg/l	0.13–22.8	6.04±6.44	0.65–42.1	7.37±9.18	<0.25–15.6	6.59± 5.64	10
20	p,p'-DDE	µg/l	<0.0005	–	< 0.0005	–	<0.0005	–	–
21	p,p'-DDD	µg/l	<0.0005	–	< 0.0005	–	<0.0005	–	–
22	p,p'-DDT	µg/l	<0.0005	–	< 0.0005	–	<0.0005	–	–
23	α-HCH	µg/l	<0.0002	–	<0.0002–4.42	–	<0.0002 – 3.07	–	–
24	β-HCH	µg/l	<0.0002	–	< 0.0002	–	<0.0002	–	–
25	δ-HCH	µg/l	<0.0002 – 2.50	–	<0.0002–2.30	–	<0.0002 – 11.8	–	–

[a] n = 60 for the parameters with Nº 1 - 5, n = 75 for the parameters with Nº 6 - 15, n = 25 for the parameters with Nº 16 – 19 and n = 4 for the parameters with Nº 20 - 25
[b] n = 48 for the parameters with Nº 1 - 5, n = 60 for the parameters with Nº 6 - 15, n = 20 for the parameters with Nº 16 – 19 and n = 4 for the parameters with Nº 20 - 25
[c] n = 40 for the parameters with Nº 1 - 5, n = 50 for the parameters with Nº 6 - 15, n = 20 for the parameters with Nº 16 – 19 and n = 4 for the parameters with Nº 20 - 25
[d] The Vietnamese Standard for coastal water quality (apply to aquaculture area)

The variation of the lagoon SAL was showed in *Figure 6*. SAL varied in the large range of $0 – 35^0/_{00}$ and increased at the two inlets (Thuan An and Tu Hien), but was relatively stable in Thuy Tu area, due to hydrodynamic condition between Thuan An and Tu Hien inlets. The highest values of SAL observed at site J30 (near Tu Hien inlets) with SAL of $30 – 35^0/_{00}$. According to Vietnam standard 28 TCN 171:2001 (SAL for black tiger shrimp culture is in the range of $10 – 30^0/_{00}$, the best range of $15 – 25^0/_{00}$), SAL at all stations from D to L in April and May was suitable for black tiger shrimp culture.

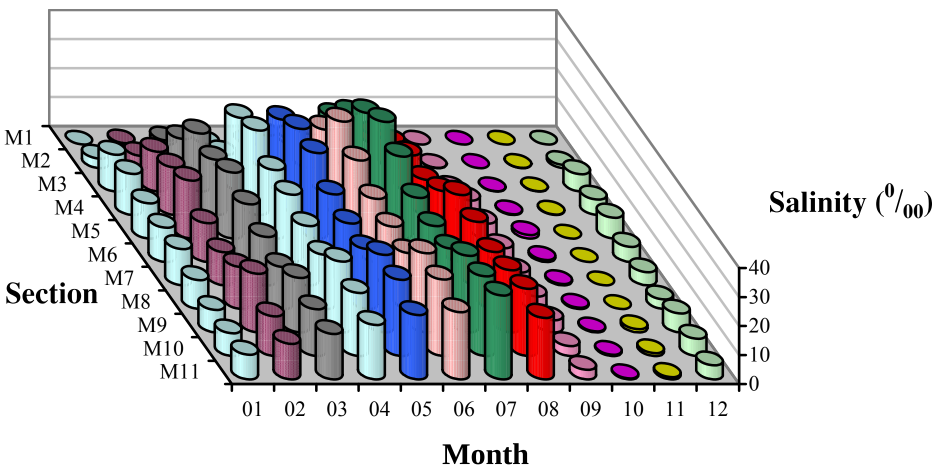

Figure 4. *The salinity variation of TG – CH lagoon in 2002* [38]

(Source: NPC,2003; M1≡A, M2≡B, M3≡D, M4≡E, M5≡F, M6≡G, M7≡H, M8≡I, M9≡J, M10≡K, M11≡L)

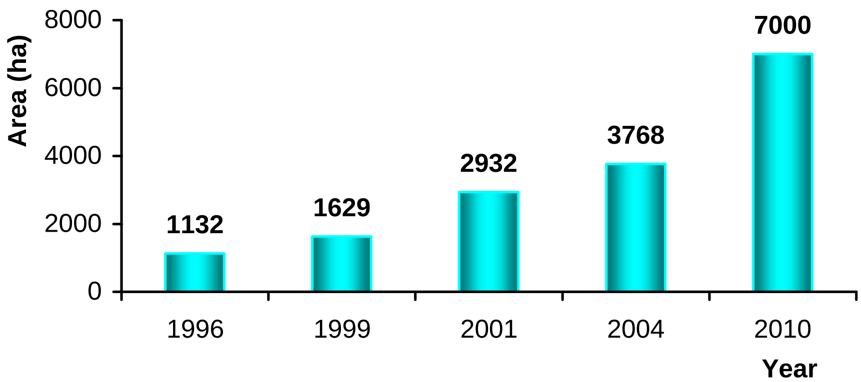

Figure 5. *Progress in area of brackish aquaculture in TG – CH lagoon from 1996 to 2010 (Source: Department of Fisheries in Thua Thien Hue, 2004)*

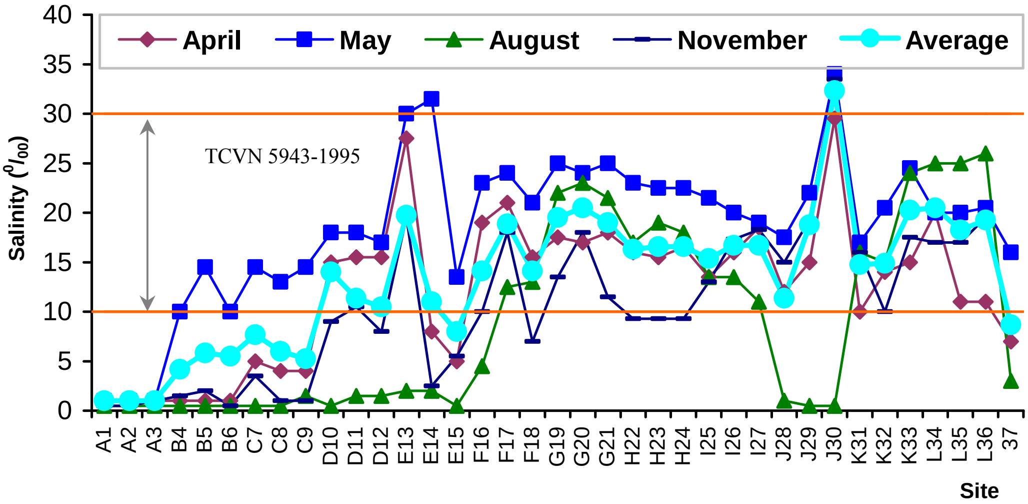

Figure 6. *The spatial and temporal variation of salinity in TG – CH lagoon*

3.1.4. Organic polution (COD and BOD) and DO

Although BOD_5 of the lagoon water met the requirement of the water used for aquaculture (according to Vietnam Standard TCVN 5943-1995), it had an increase tendency in the lagoon closed to crowded aquaculture areas such as Sam – An Truyen (between F and H sites), especially in the dry season. In the rainy season, BOD_5 of the whole lagoon was at low level in comparison with the other time of year. COD variation of the lagoon water had the same trend as BOD_5. The increases of BOD_5 and COD were obviously evidences to affirm organic pollution caused by aquaculture activities in the lagoon.

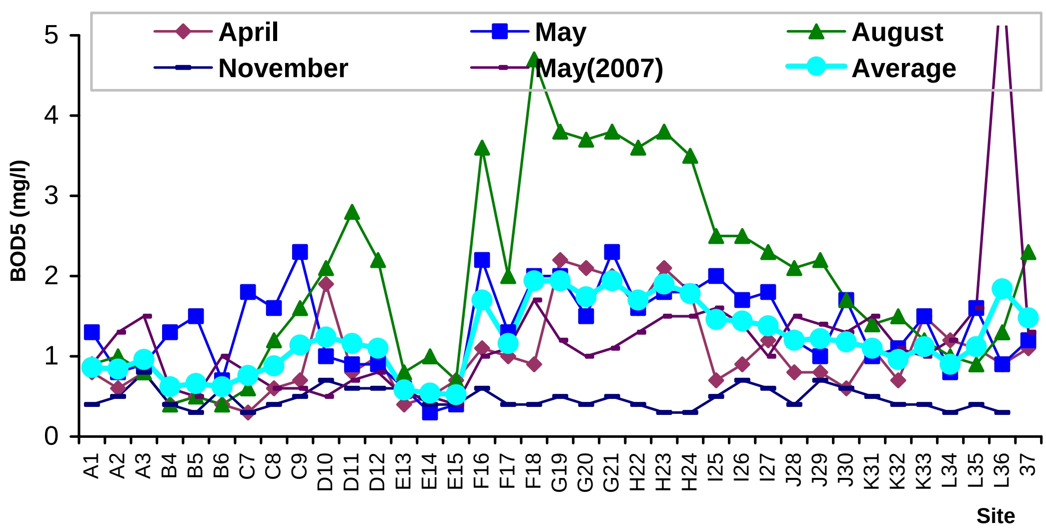

Figure 7. *The spatial and temporal variation of BOD_5 in TG – CH lagoon (2006-2007)*

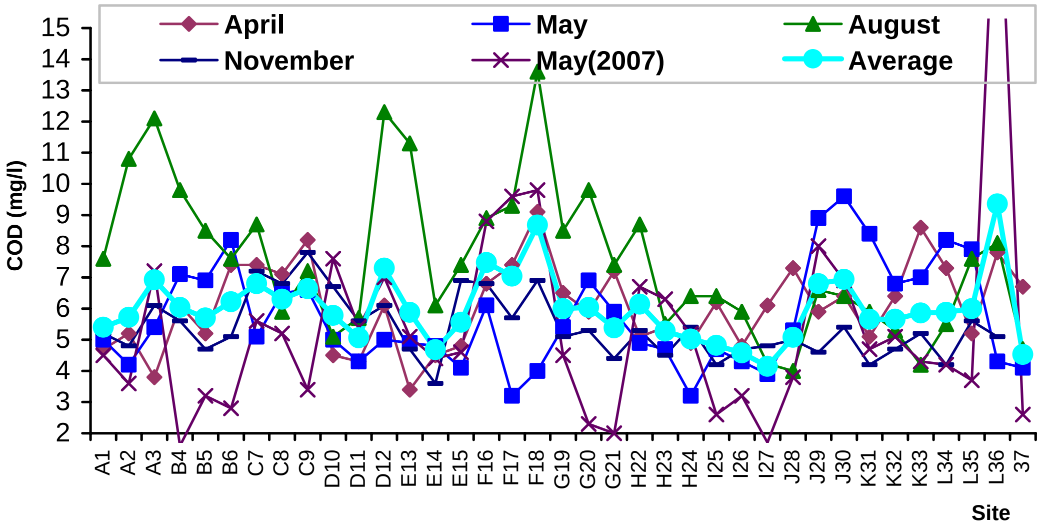

Figure 8. *The spatial and temporal variation of COD in TG – CH lagoon (2006-2007)*

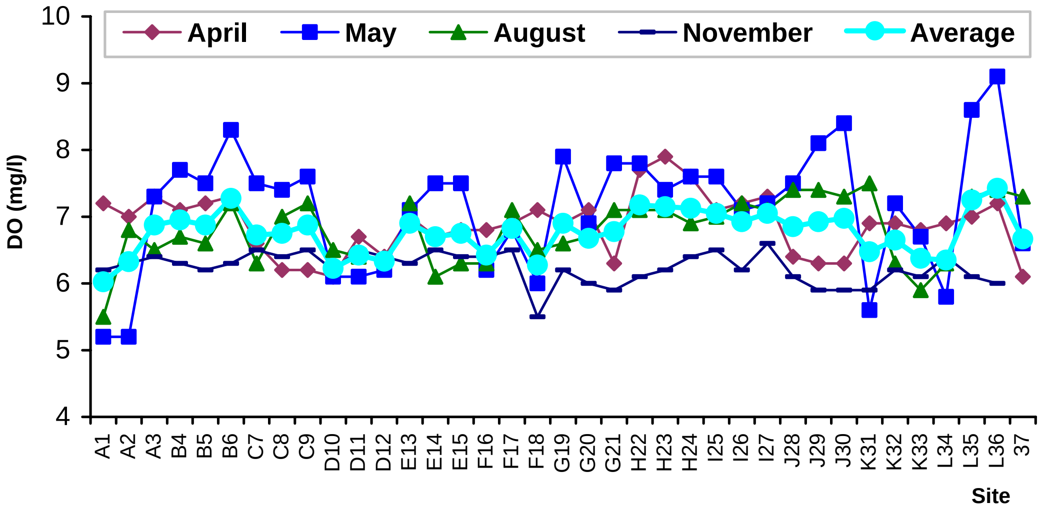

Figure 9. *The spatial and temporal variation of DO in TG – CH lagoon*

3.1.5. Nutrient pollution

- <u>*Ammonia*</u>

Up to this time, there was not much data on ammonia concentration in the lagoon. The results in *Figure 10* showed that most of ammonia concentration in the lagoon water met the requirement of Vietnam Standards TCVN 5943-1995 (N-NH4/NH3 ≤ 0,5 mg/l) and 28 TCN 171:2001 (N-NH4/NH3 ≤ 0,1 mg/l). In several stations, however, ammonia concentration exceeded the limited level of Vietnam Standard 28 TCN 171:2001, for example, at stations F, J and L in April.

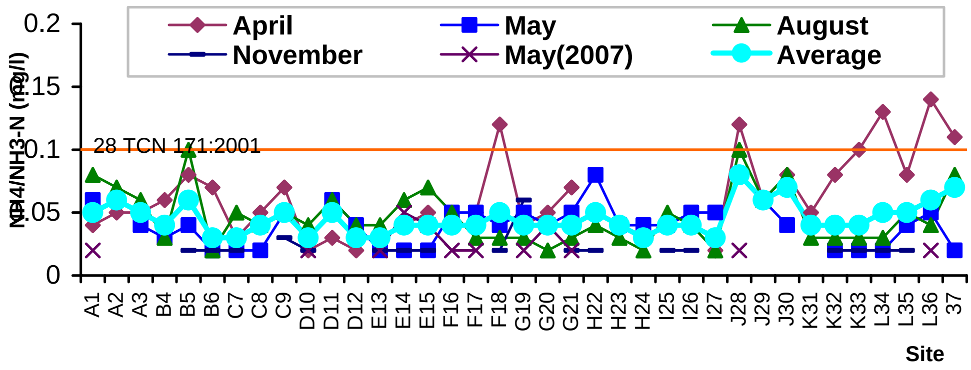

Figure 10. *The spatial and temporal variation of ammonia in TG – CH lagoon (2006-2007)*

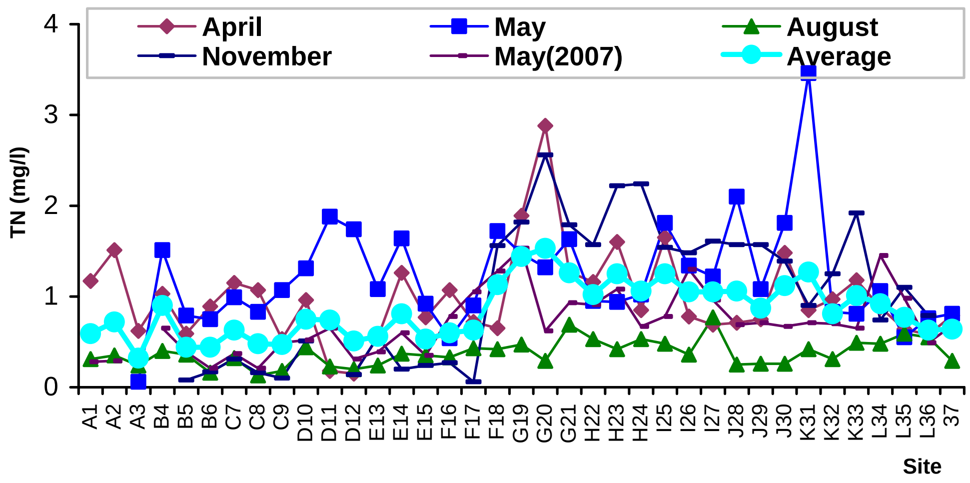

Figure 11. *The spatial and temporal variation of TN in TG – CH lagoon (2006-2007)*

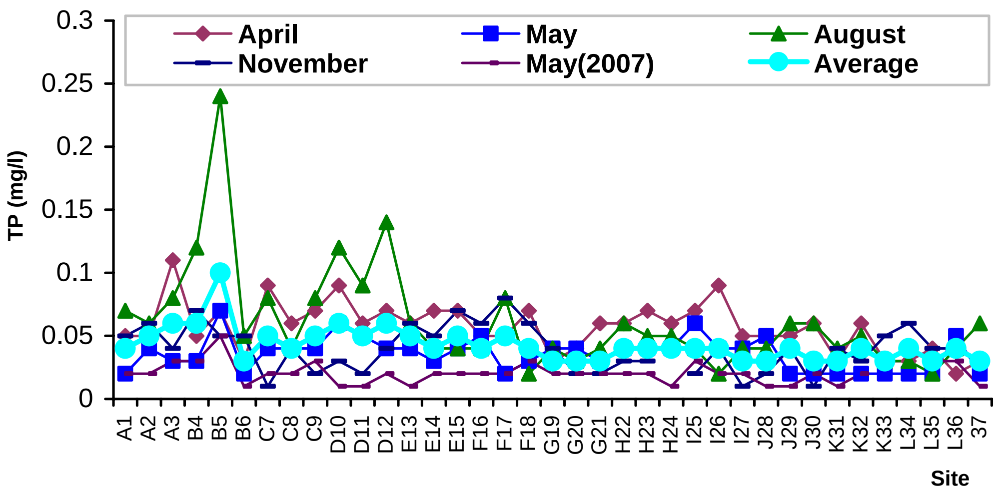

Figure 12. *The spatial and temporal variation of TP in TG – CH lagoon (2006-2007)*

- *Nitrate (NO3), phosphate (PO4), TN, TP and chlorophyll-a*

Eutrophication is one of an environmental concern for all aquatic ecosystems. Once a watershed becomes eutrophic, it can be considered as a deteriorated/“dead” system. Under eutrophic condition, it promotes development of aquatic plants (inclusive of toxic algae) and leads to damage to aquatic and wild animals, and human. At high level of nutrients it will promote rapid growth of phytoplankton and in some cases, cause undesirable “algae bloom” phenomena. The key/limiting factors causing eutrophication are nutrients (nitrogen and phosphorous) in water environment [42].

The results of this study showed that the concentrations of NO3 and PO4 were low and varied in the average range of <0.05 – 0.26 and <0.01 – 0.10 mg /L, respectively. These results agreed with the previous reports of NPC (1998 – 2003) [38] and ICZM (2002 – 2003) [8]. Although the concentration of NO3 was not high, TN level in several sites were higher than 1 mg/L (*Table 4*). According to American standard applied to coastal water (TN < 0.9 mg/L), Chinese standard to fish culture (TN < 0.5 – 1 mg/L) and Japanese standard to coastal water (TN < 0.03 – 0.05 mg/L), that TN level in the lagoon exceeded the requirements applied for coastal ecosystem conservation and aquaculture.

The ratio TN/TP in water column of a aquatic ecosystem defines which factor (nitrogen or phosphorous) limits eutrophication [42]. The limiting factor for eutrophication can be identified, based on the ratio TN/TP of fresh waters and estuarine/coastal marine waters (*Table 5*).

The ratio TN/TP of TG – CH lagoon during the study period (*Figure 13*) varied in the large range of 0.8 – 173 (mean = 4.9 – 65). The average ratio TN/TP of Cau Hai area (20 – 65) was higher than that in Thuy Tu area (11 – 61) and in Tam Giang area (5 – 25). Generally, in Tam Giang area, phosphorus was the limiting factor in April and May, while nitrogen was the limiting factor in Aug. and Nov. In Thuy Tu and Cau Hai areas, phosphorus was the limiting factor only. It was clear that the factors limiting the lagoon eutrophication depend on the time and space. In general, phosphorus was the main limiting factor for the lagoon eutrophication.

Table 5. Limiting factor of eutrophication (WHO, 2002) [42]

	Limiting factor		
	Nitrogen	Nitrogen and Phosphorus	Phosphorus
Fresh water, TN/TP	≤ 4.5	4.5 - 6	≥ 6
Estuary water / Coastal water, TN/TP	≤ 5	5 - 10	≥ 10

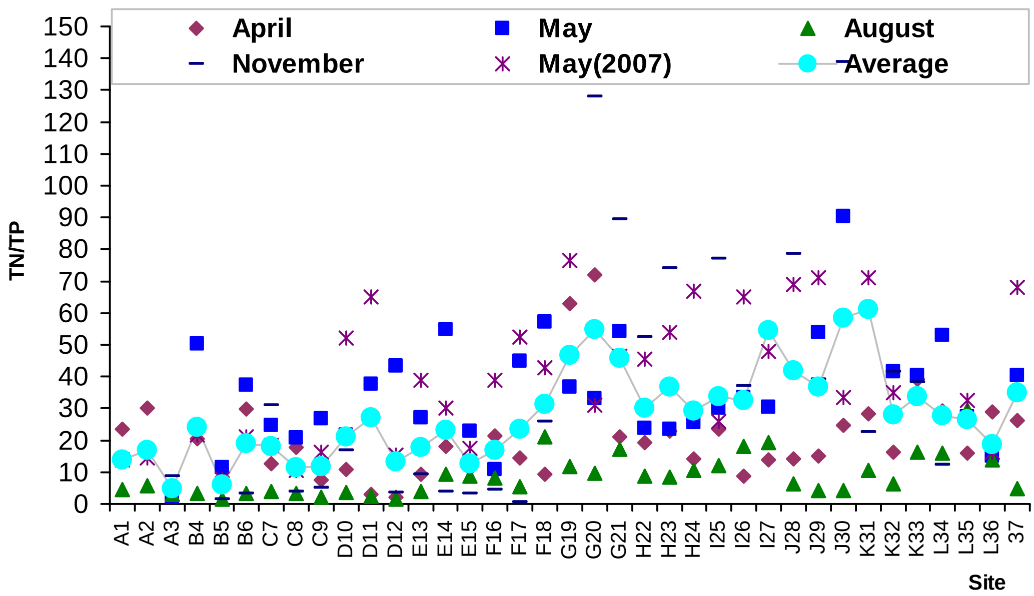

Figure 13. *The spatial and temporal variation of the ratio of TN/TP in the lagoon (2006-2007)*

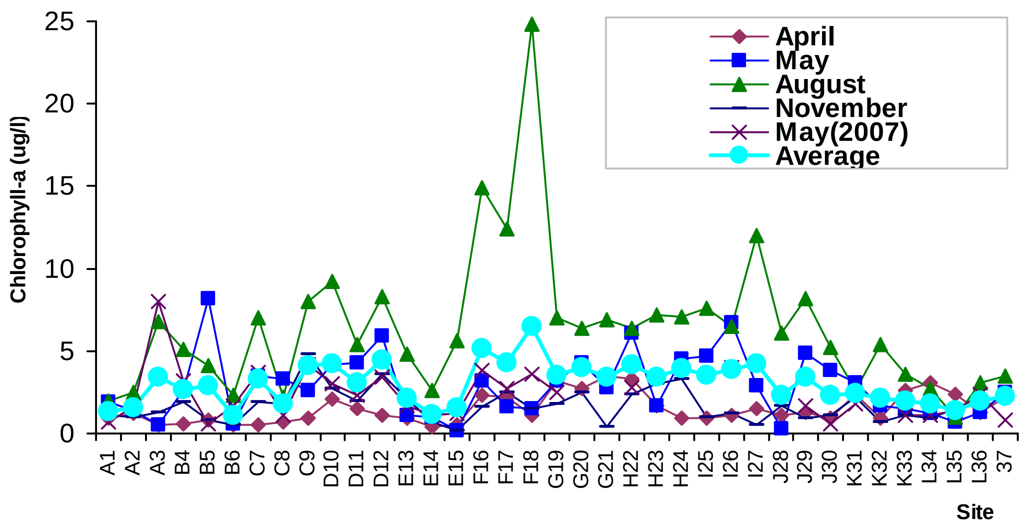

Figure 14. *The spatial and temporal variation of Chlorophyll-a in the lagoon (2006-2007)*

Once phosphorus plays role of limiting factor, PO4 concentration around 0.01 mg/L can keep normal growth of aquatic organism [4]. At PO4 levels from 0.03 to 0.1 mg/L or over, aquatic plants can be overgrown and then eutrophication appears. Because PO4 concentration in most cases during the study period was higher than 0.01 mg/L, it might be that the TG – CH lagoon has been in eutrophic condition. This remark can be further confirmed by chlorophyll-a concentration in the lagoon water.

According to Chapman (1992) [4], eutrophication occurs if chlorophyll-a concentration is in the range from 5 to 140 μg/L, meanwhile it rarely exceeds the value 2.5 μg/L in the waters under oligotrophic condition. In many samples, chlorophyll-a concentrations were higher than 5 μg/L (*Table 4* and *Figure 14*), and so that it can assert that eutrophication has occured in TG – CH lagoon, especially in the dry season.

The main sources of nutrients discharged into the lagoon were from agricultural run-off, river flows and effluents from aquaculture areas. However, in order to confirm the eutrophic condition in the lagoon and relative problems, the concentration of the nutrients (N and P) need to be monitored further. Furthermore, identification of limiting factors for eutrophication is helpful inputs very to establish a eutrophication control plan in the lagoon in the future .

3.1.6. Bacteria pollution

Average concentration of total coliform in the lagoon water (ranging from 2,900 to 69,000 MPN/100 mL) exceeded the permitted level of Vietnam standard TCVN 5943-1995 (<1000 MPN/100 mL). Also, fecal coliform concentration in the lagoon was rather high in O Lau estuary, the areas adjacent to Thuan An inlet and Sam – An Truyen area, where there are many floating boats, residential activities, markets, and poultry and aquaculture activities… Especially, in Cau Hai area, total coliform concentration was 28 to 70 times as much as the limit level of TCVN 5943-1995, and total coliform and fecal coliform concentration was many times as much as that in Thuy Tu and Tam Giang areas. Although, fecal coliform level is not included in TCVN 5943-1995, the high total coliform and fecal coliform concentration was an evidence on fecal bacteria pollution in the lagoon. Uncontrolled rapid development of aquaculture in the lagoon region and baterial pollution of river inflows have been main causes of bacterial pollution in the lagoon.

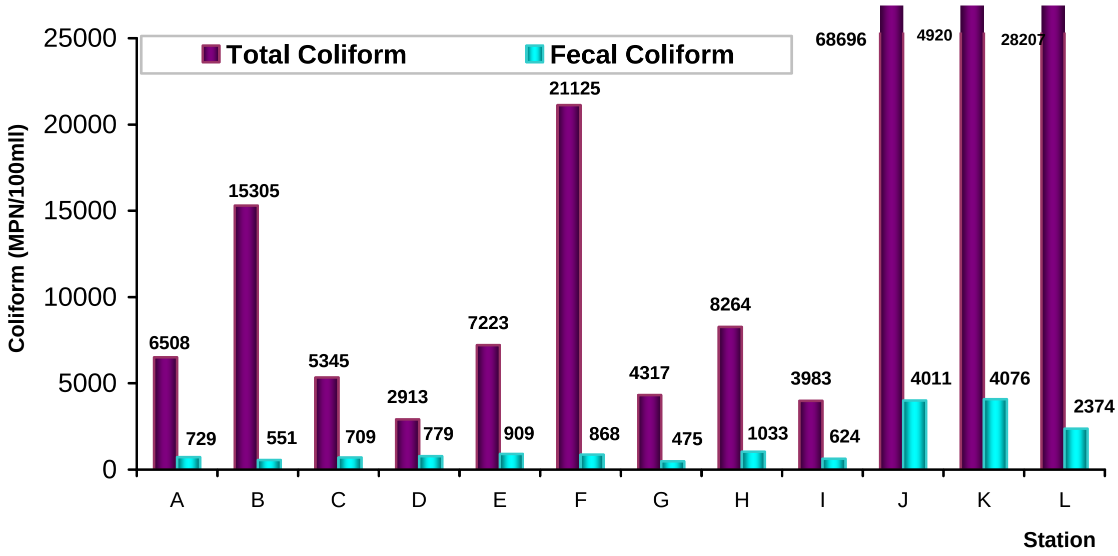

Figure 15. *The variation of average total coliform concentration at the monitoring stations in Tam Giang – Cau Hai lagoon (2006 – 2007)*

3.1.7. Organochlorine pesticides (OCs) and heavy metals (HMs)

The levels of OCs (DDTs and HCHs) in the lagoon water was lower than the detectable level of analysis method (< 0.5 ppt for DDTs and < 0.2 ppt for HCHs).

Generally, concentration of toxic metals (Cu, Pb, Cd and Zn) in the lagoon was lower than the limited level of Vietnam Standard TCVN 5943-1995. However, several data of Cu and Zn concentration exceeded the limited level of TCVN 5943-1995 (see *Table 4*). Sources of Cu and Zn discharged into the lagoon were not clearly explained. Therefore, Cu and Zn concentration in the lagoon water should be further monitored.

3.2. Sediment quality of TG – CH lagoon in 2006 and 2007

3.2.1. Sedimentary trophic characteristics

The spatial and temporal variation of sediment quality parameters such as total organic matter content (TOM), biopolymer carbon (BPC) and total phytopigment (CPE) is showed in Figures 16, 17 and 18.

– *In Tam Giang area*: TOM in the sediment ranged from 6.8 to 61.7 mg/g (average value: 31.5 mg/g) with no significant variation during the whole period. The stations with high TOM are 1, 2 and 7 with intermediate value in station 3, 4, 5 and 8. Hence, there is a decreasing gradient of TOM from North to South and from East to West. The BPC (ranging from 0.3 to 13.4 mg/g) and CPE (ranging from 5.6 to 93.8 μg/g) displayed quite similar increase of patterns from South to North but less evident and there aren't any significant patterns from East to West. Sediment of this area were characterized by a co-dominance between protein and carbohydrate; in April, the carbohydrates were dominant (48%) but during the investigated period, the protein became co-dominant in May and then largely dominant (60%) on carbohydrates (30%) in August and November.

– *In Thuan An area*: TOM ranged from 6.8 to 52.5 mg/g with a significant increment of TOM during the time, especially between April and May generalized at all station. Except station 18 that have a significant increment of TOM in August, when all other station remain at same contents or decrease. BPC (varying between 0.4 and 9.2 mg/g) and CPE (varying between 6.2 and 87.6 μg/g) displayed similarly temporal patterns with increasing of their contents during the time but not only significant in May but also in August and November. It also happened in Tam Giang area, carbohydrates (67%) dominated in the first situation, during the investigation period the domination shifted towards protein (74%).

– *In Thuy Tu area*: the temporal pattern of TOM was similar to Thuan An area with a strong increase in May and August and more stable in November. TOM ranged from 11.4 to 85.8 mg/g. BPC (varying between 1.2 and 14.9 mg/g) had a significant increase in May then decrease in August and November. Total phytopigments (varying between 6.4 and 142 μg/g) showed a rather similar temporal patterns. In some stations this increment of CPE was shifted towards August. In this area, it could be also seen that the first situation dominated by carbohydrates (47-58%) and then the domination was protein (53-74%) in August and November.

– *In Cau Hai area*: TOM ranged from 12.1 to 80.4 mg/g, with a situation more less stable excepted in stations 34 and 37 that were the most inside and far from the influence of the sea. BPC (varying between 1.3 and 8.7 mg/g) and CPE (varying between 5.1 and 85.7 μg/g) showed a similar pattern with a first increment in May decreasing in August and another increment in November. The situation displayed a co-dominance between carbohydrates and protein except August when the protein was dominant.

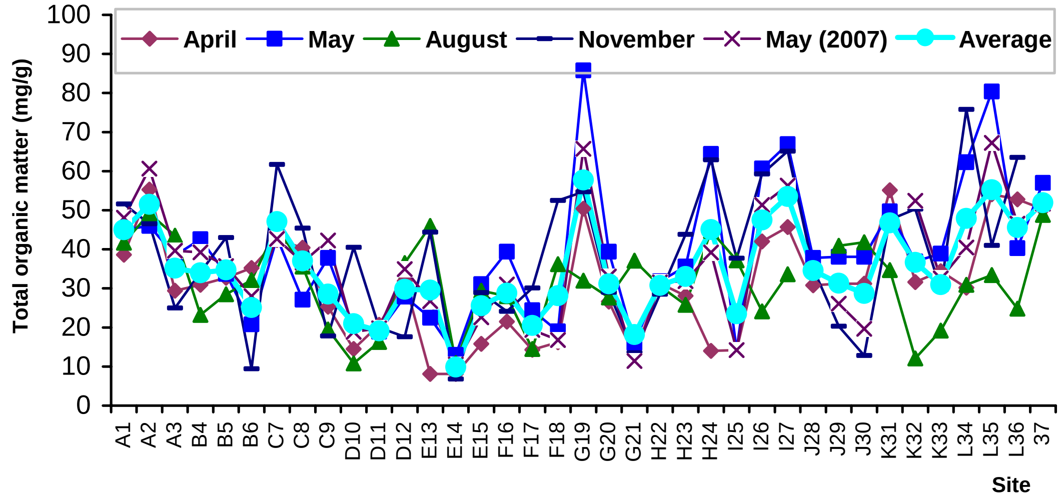

Figure 16. *The spatial and temporal variation of total organic matter in the sediment of Tam Giang – Cau Hai lagoon*

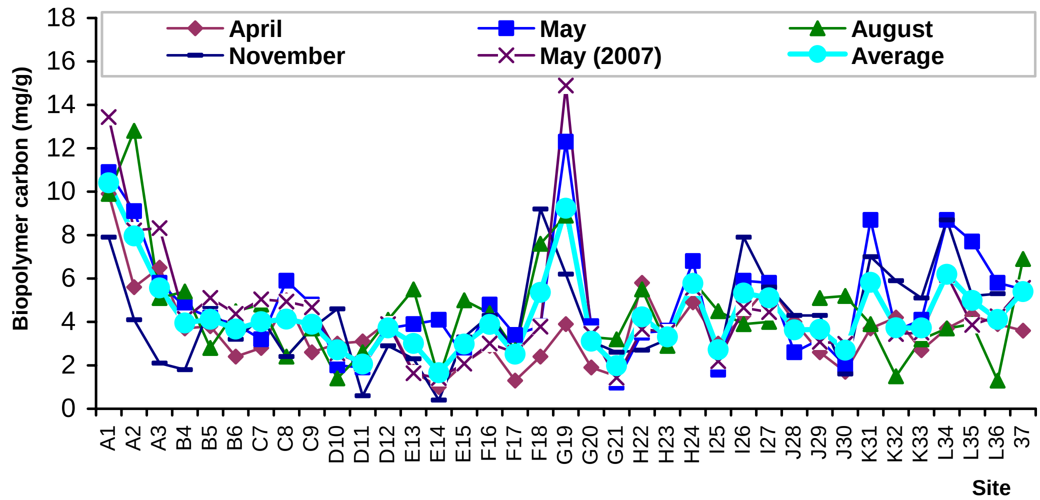

Figure 17. *The spatial and temporal variation of biopolymer carbon in the sediment of Tam Giang – Cau Hai lagoon*

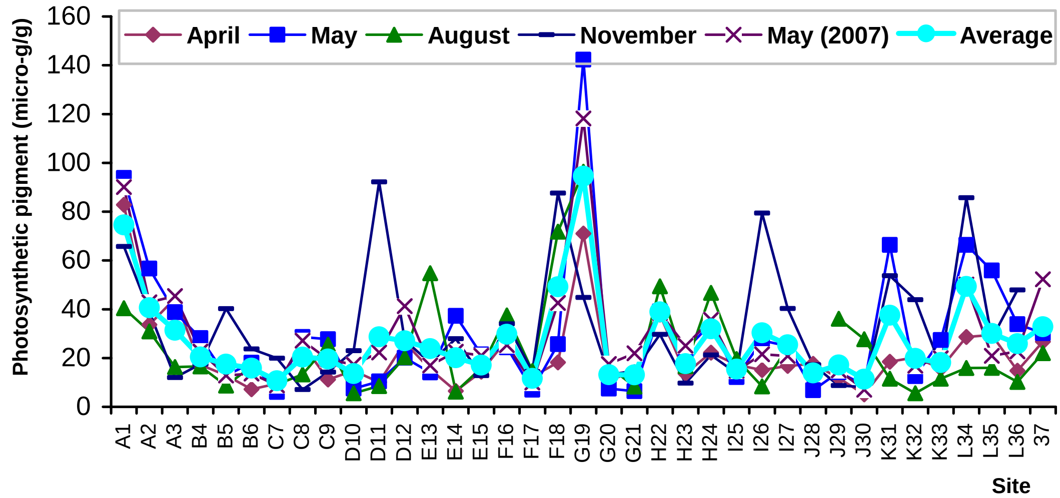

Figure 18. *The spatial and temporal variation of photosynthetic pigment in the sediment of Tam Giang – Cau Hai lagoon*

3.2.2. Trophic biochemical index

The variables used so far for the analysis of the trophic state of marine ecosystems (e.g., nutrient concentrations and phytoplankton biomass) are typically determined only in the water column, even though the detrimental effects of eutrophication and dystrophic crises begin and develop in the benthic domain. Therefore, there is a strong need of identifying new and integrated ecological descriptors of the trophic state of benthic marine systems, where the eutrophication process is primed and determines the worst effects. This can be pursued effectively if we search for in situ variables related to the direct consequences of eutrophication, rather than limit our search simply to potential precursor variables (e.g. inorganic nutrients in the water column).

Primary production export, lateral advection of detrital C and in situ organic C production are spatially and temporally integrated by sediment records. In fact, the benthic domain, being a tank of organic matter, acts as a “recorder” of processes occurring in the entire ecosystems, at least when shallow water systems are considered [7,9,17,23]. In all marine ecosystems, the largest fraction of organic matter in the sediment is accounted by organic detritus (i.e. non living organic material) [40,41], which certainly contributes to the trophic state of a given system, but it is generally completely neglected by trophodynamic studies.

In the present report, we propose a new approach for the assessment of marine ecosystems’ trophic state focused on the quantity and biochemical composition of the sediment organic matter, in which, together with proxies of primary production (e.g. phytopigments), the detrital fractions of sediment organic matter are also taken in to account.

In this study, irrespectively from the investigated area, BPC was significantly related ($p < 0.001$, $R = 0.866$) with PCE (*Figure 19*). PCE explained more than 75% of BPC, which indicated that in shallow coastal ecosystems BPC is tightly dependent on the inputs from primary production. However, since the determination of phytopigments in the sediment does not allow discriminating between inputs from the water column and microphytobenthic biomass, this result does not provide any information on the actual significance of in situ primary productivity versus the export from the water column.

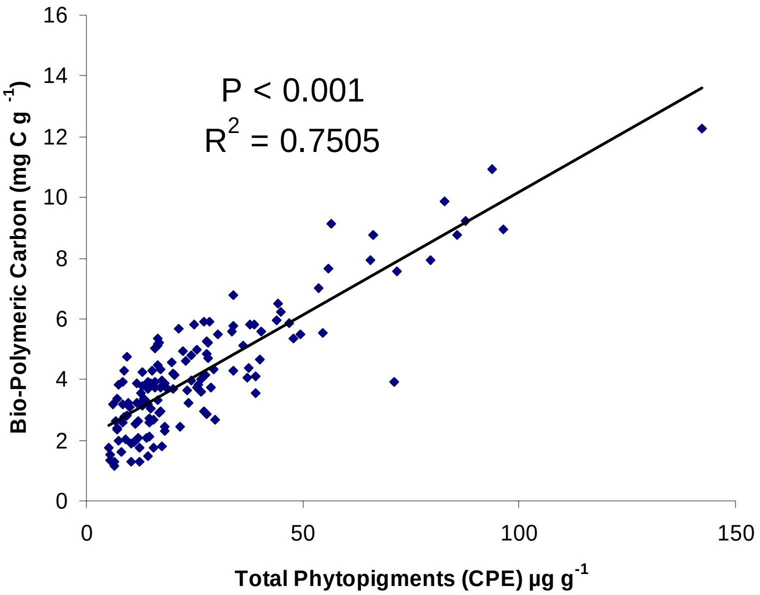

Figure 19*. Correlation between BPC and CPE in all area of Tam Giang – Cau Hai lagoon in April, May, August and November of 2006*

In the investigated sediments, the contribution of primary organic matter (microphyto-benthic biomass) to BPC averaged 8%, ranging from 2 to 40%, indicating that the investigated systems were largely dominated (60-98%) by organic matter detrital or heterotrophic in nature. Also we could observe a temporal pattern different for area.

– In Tam Giang area, the contribution of primary organic matter to BPC is around 6% until November when the rise until 20%. This pattern could be showed a detrital dominated system until November when the rainy season drive in the lagoon a huge of nutrient that make more important the contribute of primary production to carbon supply.

– In Thuan An area too, we have an increment in November but here displayed an important contribution of autotrophic fraction in April too, showing the effect of hydrodynamism on the origin of organic matter: high level of hydrodynamic condition usually make more relevant the autotrophic fraction of BPC.

– In Thuy Tu and especially in Cau Hai, the absence of important hydrodynamic condition and the imput of organic matter basically from fish farm, we didn't observe temporal patterns but the situation is more stable and detritus fraction was largely dominant (90% and more than 95% in Thuy Tu and Cau Hai respectively).

Since the biochemical composition of the sediment organic matter is influenced by its origin, both the variable contribution of the autotrophic fraction and differences in the characteristics of the primary producers can result in the differences in the relative importance of the main biochemical classes of organic compounds to the bulk of organic matter [26]. Previous studies demonstrated that systems characterised by different trophic conditions display the clear differences in the biochemical composition of sediment organic matter. Generally, systems canonically defined oligotrophic (in terms of nutrients available in the water column) display the clear dominance of the carbohydrate fraction, whereas eutrophic systems are typically characterised by the clear protein dominance [11,32].

In this study we found that the biochemical composition of sediment organic matter increase the protein to carbohydrates ratio passing from an average of 0.7-0.8 in April and May to more than 2 in August and November at all investigated areas. This result confirms that the process of BPC accumulation in the sediment, as the one observed in those case, is typically accompanied by a shift of dominance from carbohydrate- to protein-dominated sediments and usually increased lipid fraction that here we couldn't saw. On one side, this can be partially explained by the fact that eutrophicated systems, which produce a much higher amount of organic matter, tend to accumulate N-rich compounds [9]. We could identify threshold levels of these two descriptors for oligo-, meso- and eutrophic benthic systems, showed in *Table 6* [32].

Applying this table to our result, we could said that the sediment of whole lagoon for all period study was in a situation of eutrophication, except Thuan An area in April and November and Tam Giang only in April when the trophic state was mesotrophic. Only Cau Hai, for the period of November was in a situation of pertrophic state. This one could be explained: in Tam Giang and Thuan An the accumulation of organic matter are balanced from the export towards the sea, so only in the period when there is not a strong primary production the trophic state could become eutrophic. In Thuy Tu and especially in Cau Hai, there isn't the same change to export the organic detrital matter, so this one could be accumulated in the sediment and increase the risk of pertrophic state and consequently the risk of a oxygenation crisis of the bottom of lagoon.

***Table 6**. The strophic classification of benthic systems according to the biopolymer carbon and autotrophic fraction* [32]

Trophic state	Biopolymeric Carbon (mg-C/g)	Autotrophic fraction of BPC (%)
Oligotrophic	< 1	> 15
Mesotrophic	1-5	8-15
Eutrophic	> 5	< 8

3.2.3. Organochlorine pesticides (OCs) and heavy metals

To assess OCs and heavy metals level in the lagoon sediment, we use Canadian Sediment Quality Guideline (CSQG, 2002) [2] for marine sediment (Interim Sediment Quality Guideline – ISQG and probable effect level – PEL), because there is no Vietnam Guidelines for OCs and heavy metals in marine sediment, so far.

The OCs content in the sediment of TG – CH lagoon was also rather low. The DDTs contents in the lagoon sediment samples (based on dry weight) were 1.84; 2.32 and 3.48 µg/kg (ppb) in Cau Hai, Thuy Tu and Tam Giang, respectively. However, DDTs levels (ranging from 4.65 to 10.3 ppb) in station C (Tam Giang area) were higher than that of ISQG applied to marine sediment (4.48 ppb), but lower than that of PEL applied to marine sediment (16.32 ppb). *Figure 20* shows the variation of DDTs content in 2006 and 2007. DDTs levels in the sediment samples in the areas adjacent to Thuan An inlet (stations C, D, E and F) were higher than those in the north of Tam Giang area and Cau Hai area.

The average contents of HCHs (total HCHs) in the lagoon sediment samples were rather high. The HCHs levels were the same in the areas of Tam Giang, Thuy Tu and Cau Hai (*Figure 20*) with their values of 1.7, 1.8 and 1.2 ppb; respectively. The HCHs levels were 4 – 6 times higher than those of ISQG (0.32 ppb) and equal to the level of PEL (0.99 ppb) applied to marine sediment. Generally, the results under study indicated that the contents of OCs in Thuan An area were higher than that in other areas. The temperal variation of the OCs content during the investigated period was insignificant. Comparing with the previous study [36], the average level of HCHs under this study was 2 times lower, meanwhile, the DDTs level observed was 8 – 10 times lower.

The high OCs content in the lagoon sediment may lead to adverse effects on the benthic species such as bivalves (mussels, clams…) and benthic fish (local carps, rabbifish…), because of accumulation and biomagnification via food chains. However, mornitoring of OCs in the lagoon sediment should be made further in order to confirm the above observations.

Heavy metals level in the lagoon sediment, in general, was lower than that of ISQG and PEL for marine sediment. However, the heavy metal levels in a few sediment samples were much higher than that of ISQG and PEL. For example, Cd level of 22,800 ppb in the sediment sample taken at site E in May 2006 and Cu level of 110,800 ppb at station K in November 2006 were much higher than that of ISQG and PEL. The reasons for these were not clearly. Therefore, the heavy metals in the lagoon sediment should be further monitored in order to give more confident conclusion.

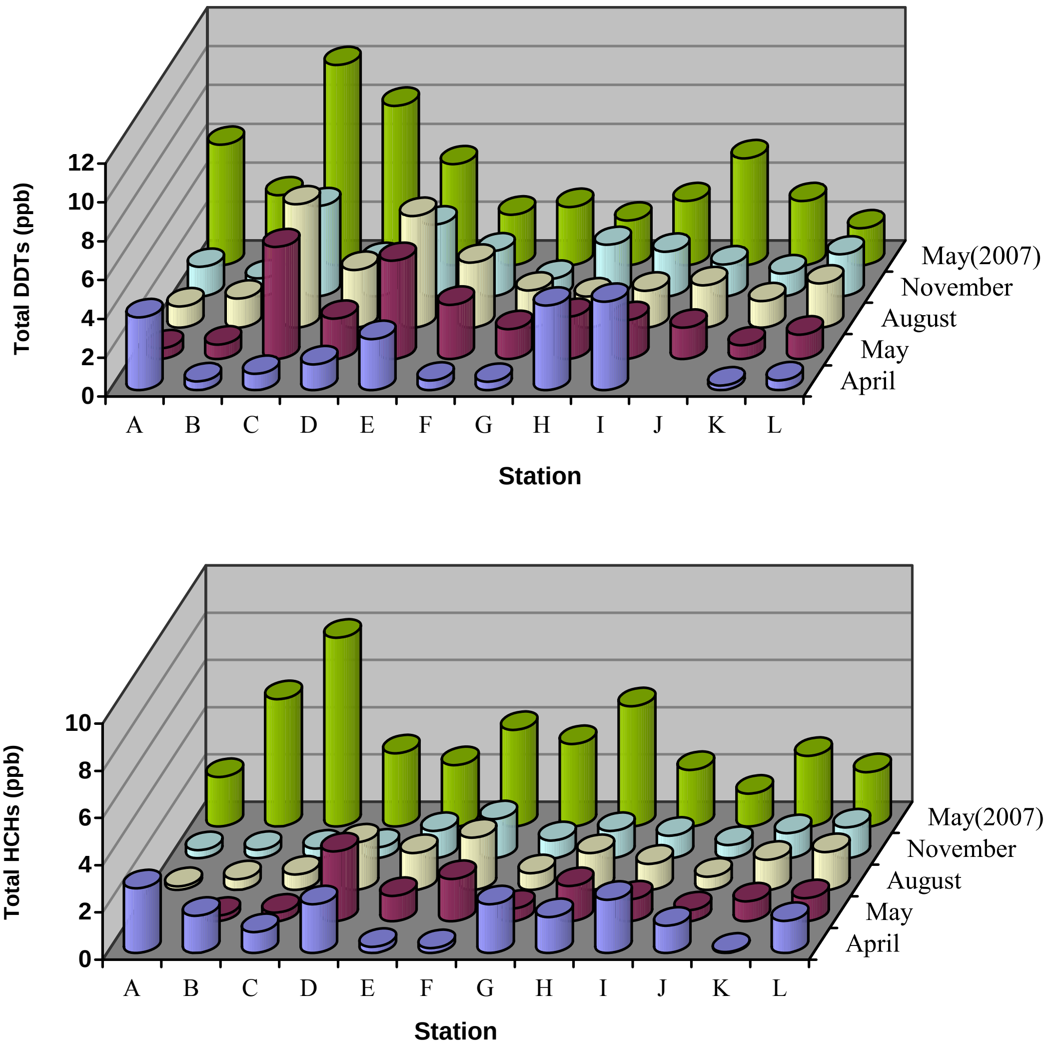

***Figure 20**. The spatial and temporal variation of total DDTs and HCHs in the sediment of Tam Giang – Cau Hai lagoon (2006 – 2007)*

***Table 7.** Summary of sediment quality characteristics of Tam Giang – Cau Hai lagoon (4, 5, 8, 11/2006 and 5/2007)*

Nº	Parameters	Unit	Tam Giang		Thuy Tu		Cau Hai		EQGs[d]
			Min – Max	Mean ± S[a]	Min – Max	Mean ± S[b]	Min – Max	Mean ± S[c]	
1	Total organic matter	mg/g	6.8 – 61.7	31.5 ± 13.1	11.4 – 85.8	34.8 ± 17.0	12.1 – 80.4	40.8 ± 15.1	–
2	Lipids	mg/g	0.01 – 2.7	0.52 ± 0.51	0.10 – 1.4	0.51 ± 0.34	0.03 – 2.0	0.55 ± 0.43	–
3	Carbohydrates	mg/g	0.30 – 20.6	4.78 ± 3.52	0.60 – 18.3	4.63 ± 2.91.90	0.40 – 12.9	4.84 ± 3.13	–
4	Protein	mg/g	0.01 – 13.1	3.99 ± 2.99	0.5 – 14.5	4.36 ± 3.24	1.30 – 9.90	4.16 ± 2.03	–
5	Chlorophyll-a (Chl-a)	µg/g	1.21 – 32.1	8.32 ± 6.52	1.90 – 58.9	12.0 ± 12.5	1.45 – 22.4	7.58 ± 5.79	–
6	Phaeopigments	µg/g	2.61 – 75.4	17.1 ± 14.5	2.34 – 83.4	19.0 ± 16.1	3.25 – 68.9	18.1 ± 13.9	–
7	Cytopathic effects (CPE)	µg/g	5.64 – 93.8	25.4 ± 20.0	6.43 – 142	31.0 ± 27.2	5.06 – 85.7	25.7 ± 18.6	–
8	Chl-a/CPE	%	13.9 – 63.5	32.6 ± 11.2	9.18 – 72.1	37.3 ± 14.1	13.6 – 61.8	30.2 ± 9.12	–
9	Biopolymeric carbon	mg/g	0.33 – 13.4	4.26 ± 2.62	1.2 – 14.89	4.38 ± 2.49	1.30 – 8.70	4.37 ± 1.84	–
10	Biopolymeric carbon	%	1.78 – 35.7	12.58 ± 7.20	5.50 – 57.5	14.0 ± 8.57	4.40 – 24.5	11.4 ± 4.99	–
11	Cu	mg/kg	1.46–760	146±244	0.88–109	104±285	0.44–456	84.2±149	108
12	Pb	mg/kg	6.97–42.9	18.9±8.97	4.24–44.6	20.8±12.3	11.8–55.4	277±123	112
13	Cd	mg/kg	0.08–22.8	1.53±4.47	0.05–1.20	0.45±0.33	0.10–4.81	0.88±1.17	4.2
14	Zn	mg/kg	10.2–106	48.4±27.5	7.56–137	513±346	5.24–136	570±39.9	271
15	p,p'-DDE	µg/kg	0.19–2.40	0.84±0.45	<0.15–2.00	0.89±0.46	<0.15–2.80	0.67±0.64	3.74
16	p,p'-DDD	µg/kg	<0.15–4.50	1.65±1.32	<0.15–2.50	1.25±0.63	<0.15–1.60	0.86±0.31	7.81
17	p,p'-DDT	µg/kg	<0.15–8.40	1.70±2.10	<0.15–3.64	1.25±1.04	<0.15–1.80	0.68±0.50	4.77
18	Total DDT	µg/kg	0.45–10.3	3.48±2.62	0.43–4.55	2.32±1.09	0.24–5.50	1.84±1.32	–
19	α-HCH	µg/kg	<0.05–3.80	0.52±0.73	<0.15–1.80	0.28±0.38	<0.05–0.50	0.26±0.14	–
20	β-HCH	µg/kg	<0.05–4.60	1.40±1.71	<0.05–2.00	1.43±0.51	<0.05–1.40	0.77±0.51	–
21	δ-HCH	µg/kg	<0.05–2.70	1.11±0.81	0.07–3.70	1.32±0.80	<0.15–1.40	0.81±0.39	–
22	Total HCH	µg/kg	0.15–8.00	1.70±1.85	0.21–5.10	1.80±1.23	0.05–3.00	1.19±0.74	0.99

[a] n = 75 for the parameters with Nº 1–10 and n = 25 for the other parameters; [b] n = 60 for the parameters with Nº 1–10 and n = 20 for the other parameters
[c] n = 48 for the parameters with Nº 1–10 and n = 15 for the other parameters; [d] Canadian Environmental Quality Guidelines for marine sediment

3.3. Water quality of the canals adjacent to aquaculture ponds in 2006 and 2007

Most of water quality parameters (*Table 8*) of the channel adjacent to aquaculture ponds met the requirement of Vietnam Standard TCVN 5943−1995 (applied to the coastal water quality used for aquaculture) and 28 TCN 171:2001 issued by Ministry of Fisheries (applied to intensive culture of black tiger shrimp).

Table 8*. Water quality parameters of the canals adjacent to the aquaculture ponds in Tam Giang – Thuy Tu (4, 5, 8, 11/2006 and 5/2007)*

N^o	Parameters	Unit	Sam – An Truyen		Quang An		28 TCVN 171:2001$^{(*)}$
			Min – Max	Mean ± S (n=25)	Min – Max	Mean ± S (n=15)	
1	pH		6.4 – 9.3	8.1 ± 0.8	6.6 – 8.5	7.7 ± 0.7	7.5 – 8.5
2	EC	mS/cm	0.9 – 37.4	17.2 ± 12.1	0.2 – 36.7	16.1 ± 13.5	–
3	Salinity	$^0/_{00}$	0.5 – 22.8	10.0 ± 7.5	0.1 – 22.2	9.4 ± 8.2	10 – 30
4	SS	mg/l	1 – 12	6 ± 3	3 – 31	9 ± 8	–
5	Turbidity	NTU	1 – 13	6 ± 3	4 – 36	10 ± 9	–
6	DO	mg/l	5.6 – 8.4	7.0 ± 0.7	5.1 – 7.6	6.6 ± 0.8	> 5
7	BOD5	mg/l	0.5 – 3.3	1.4 ± 0.7	0.5 – 4	2 ± 1	< 10
8	COD	mg/l	5.1 – 27.2	10.8 ± 4.9	6 – 13	10 ± 3	–
9	N-NH4/NH3	mg/l	<0.02 – 0.22	0.06±0.05	<0.02 – 0.10	0.05±0.03	< 0.1
10	N-NO3	mg/l	<0.05 – 0.07	0.06±0.01	<0.05 – 0.06	0.06±0.01	–
11	P-PO4	mg/l	<0.01 – 1.1	0.54±0.50	<0.01 – 0.01	0.53±0.50	–
12	TN	mg/l	<0.01 – 1.9	0.56±0.51	<0.01 – 2.11	0.57±0.59	–
13	TP	mg/l	<0.01 – 0.07	0.05±0.02	0.01 – 0.04	0.03-0.01	–

$^{(*)}$ *The Vietnamese Standard for intensive cultivation of black tiger shrimp (Defined by Ministry of Fisheries).*

3.3.1. pH

Difference between the pH of the canals adjacent to aquaculture ponds and that of the lagoon water was insignificant (*Figure 21*). The results obtained from the previous study (ICZM project, 2002 – 2003) in Quang An and Sam – An Truyen areas were shown in *Figure 21* with the aim of comparison. Due to adjacent to Thuan An inlet, the water pH in Sam – An Truyen area was higher than that in Quang An area. The pH in the canals adjacent to aquaculture ponds met the requirement of Vietnam Standard 28 TCN 171:2001 applied to intensive culture of black tiger shrimp.

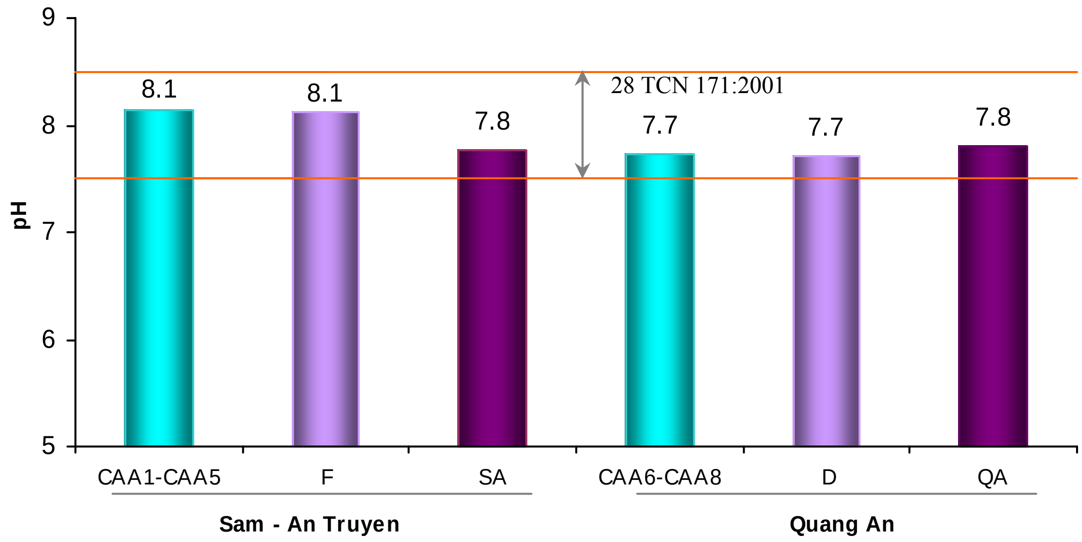

Figure 21. *The variation of average water pH in the chanels adjacent to aquaculture ponds*

(CAA1-CAA5: average value of samples from CAA1 to CAA5; SA: average value during 8, 11- 2002 and 4, 5 - 2003 (ICZM); CAA6-CAA8: everage value of samples from CAA6 to CAA8; QA: everage value during 8, 11 - 2002 and 4, 5 - 2003 (ICZM); F and D: monitering sites inside the lagoon and next to the ponds; SA and QA samples are taken at the chanels next to the ponds)

3.3.2. Salinity

In April and May, salinity in the lagoon sastified the requirements of the intensive culture of black tiger shrimp (according to the Standard 28 TCN 171:2001) (*Figure 22*).

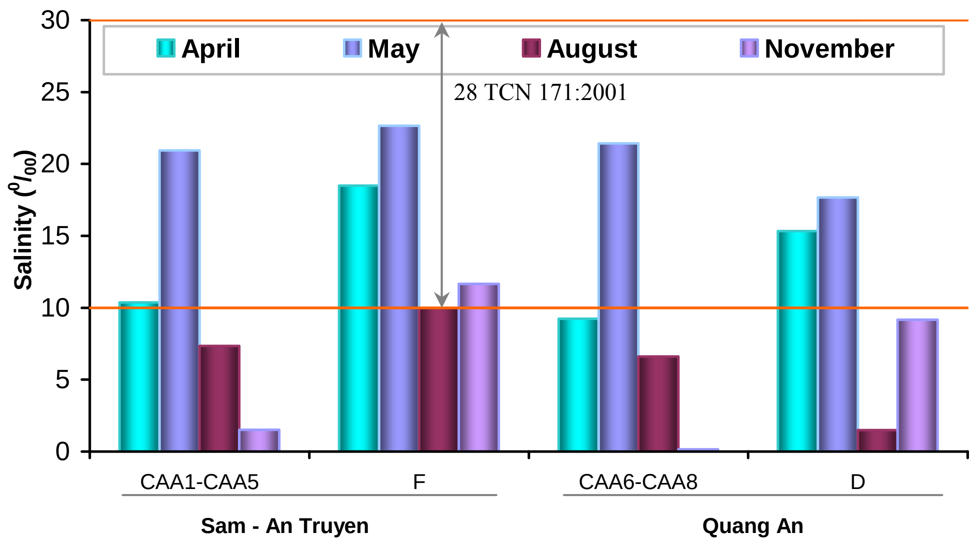

Figure 22. *Average salinity in the canals adjacent to aquaculture ponds*

3.3.3. Organic pollution (COD and BOD) and DO

In general, BOD_5 in the canals was low. The average BOD_5 was in the range of 1.4 – 2 mg/L and met the requirement of the Standard 28 TCN 171:2001 (BOD_5 < 10 mg/L). COD in the canals was higher than that in the neighbourhood lagoon, but much lower the results reported by ICZM project (2003). It indicated obviously that aquaculture activities caused the increase in organic pollution both in the canals and the lagoon.

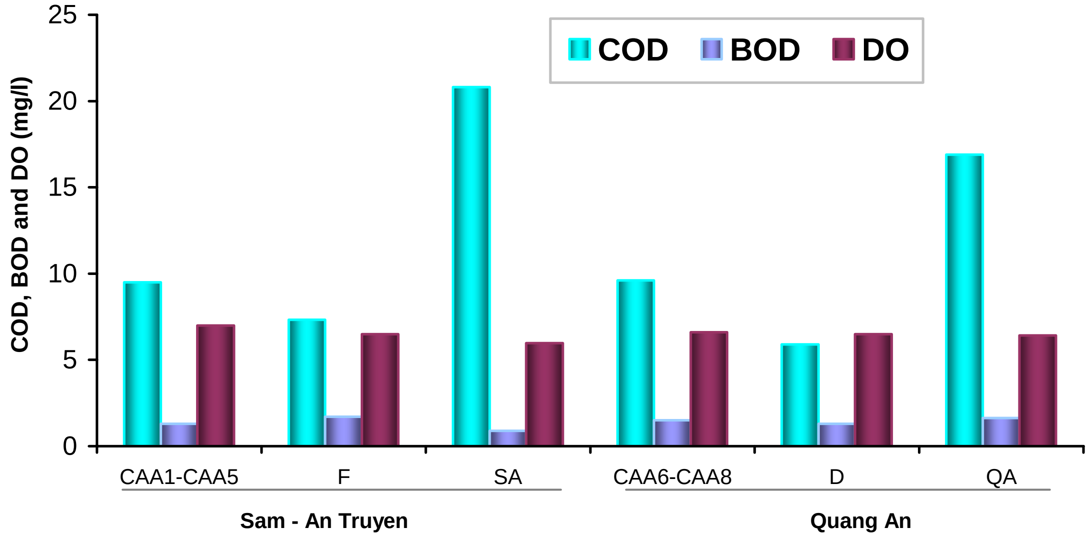

Figure 23. *DO and oxygen demand in the canals adjacent to aquaculture ponds*

3.3.4. Nutrients (nitrate, phosphate, TN and TP)

The nutrients concentration in the canals adjacent to aquaculture ponds varied insignificantly during the study period (see *Table 9*). The nutrients concentration in the canals was lower than that in the neighbourhood lagoon (*Figure 24*). These results agreed with that reported by ICZM project (data of 8, 9, 10 and 11/2002 and 3, 4, 5, and 6/2003). However, according to the report of ICZM project (2003), in Loc Dien and Vinh Giang (belonging to Cau Hai area), the nutrient concentration in the canals was higher than that in the neighbourhood lagoon.

Table 9 *. Variation range of nitrate, phosphate, TN and TP concentration in the canals adjacent to aquaculture ponds and the neighbourhood lagoon (F and D stations) in 2006 and 2007*

Pond area/ Neighbourhood	N-NO3 (mg/l)	P-PO4 (mg/l)	TN (mg/l)	TP (mg/l)
CAA1-CAA5	<0.05-0.07	<0.01-0.05	0.18-1.90	<0.01-0.07
F	<0.05-0.13	<0.01-0.05	0.27-1.72	0.02-0.08
CAA6-CAA8	<0.05-0.06	<0.01-0.01	0.16-2.11	<0.01-0.04
D	<0.05-0.17	<0.01-0.08	<0.05-1.88	0.02-0.12

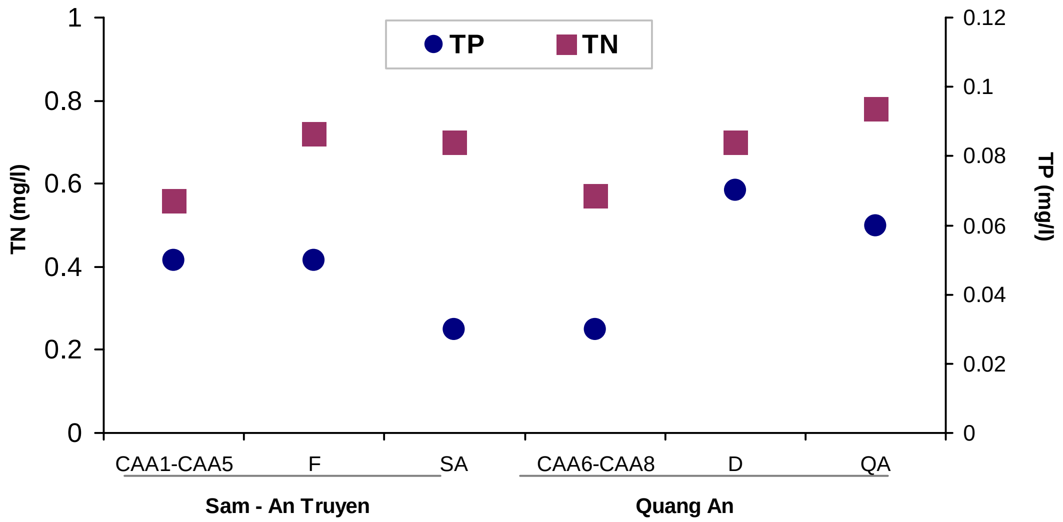

Figure 24. *Average values of TN and TP in the canals adjacent to aquacultrure ponds (2006 – 2007)*

3. 4. Trends and changes in lagoon water and sediment quality in recent years

3.4.1. Organic pollution

A rapid increase in the aquaculture area, mainly shrimp culture, between 2000 and 2004 resulted in increased organic pollution, especially in the dry seasons. Due to uncontrolled and widespread aquatic diseases in the period 2004 to 2006, the aquaculture area did not increase and investment by the local people into aquaculture declined. This appears to have facilitated self-purification of the lagoon and a decrease in organic pollution between 2004 and 2006 (see *Figures 25 and 26*).

Organic pollution leads to decreased dissolved oxygen (DO) levels in the water (*Figure 27*), as biological decomposition of the organic compounds consumes DO in the water under the catalytic effect of micro-organisms. The increase in organic pollution from 1998 to 2004, especially in places close to crowded aquaculture areas such as Quang An, Quang Phuoc and Sam-An Truyen, resulted in a decrease of the ‘lagoon health’, because the DO level is very important to any aquatic ecosystem. The DO decrease adversely impacted the lagoon ecosystem and aquaculture. Organic pollution in aquaculture ponds and channels close to the ponds was found to be more severe than that in the lagoon with BOD_5 levels two times higher than that in the lagoon [1]. It should be noted that organic pollution is caused by not only increased aquaculture but also other sources such as organic pollution in the river water discharged into the lagoon, domestic and sewage wastes from the people living around the lagoon, and run-off from farmland areas.

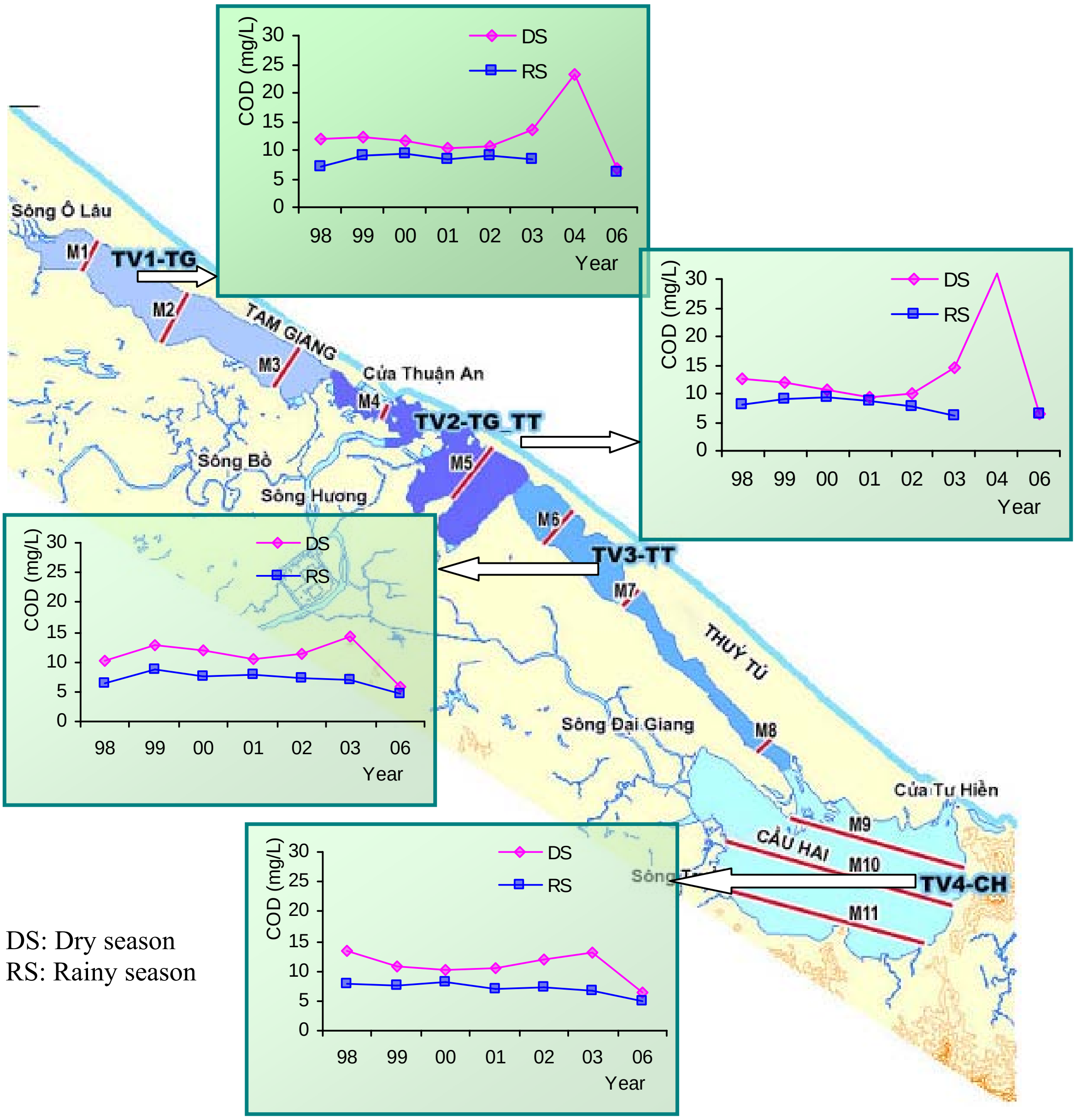

Figure 25. *Temporal and spatial change of COD in 4 major areas of the lagoon (1998 – 2006)*

Data source (monthly average data):

Year 1998 – 2001 (NPC, 2003) [38]

Year 2002: From January to December (NPC, 2003) [38]; from August to November (Ton That Phap et al., 2003) [8,31]

Year 2003: From January to May (NPC, 2003); from March to June and from October to November (Ton That Phap et al., 2003.) [8,31]

Year 2004: From February to May (Nguyen Hoai Son, 2004)

Year 2006: From February to May and July (Tran Van Hai, 2006) [18]; April, May, August and November (IMOLA, 2006).

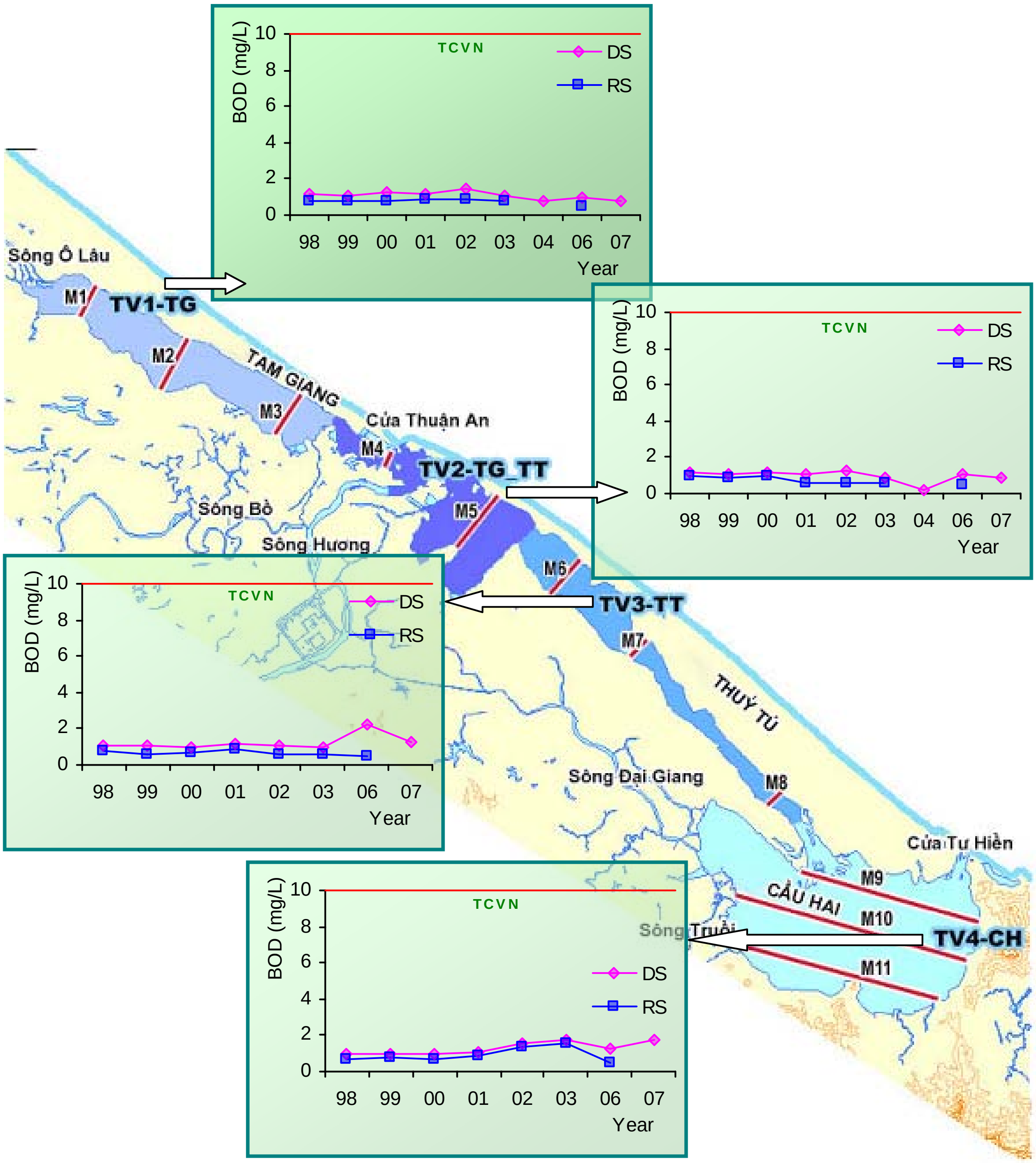

Figure 26. *Temporal and spatial change of BOD5 in 4 major areas of the lagoon (1998 – 2006)*

Data source (monthly average data):

Year 1998 – 2001 (NPC, 2003) [38]

Year 2002: From January to December (NPC, 2003) [38]; from August to November (Ton That Phap et al., 2003) [8,31]

Year 2003: From January to May (NPC, 2003); from March to June and from October to November (Ton That Phap et al., 2003.) [8,31]

Year 2004: From February to May (Nguyen Hoai Son, 2004)

Year 2006: From February to May and July (Tran Van Hai, 2006) [18]; April, May, August and November (IMOLA, 2006).

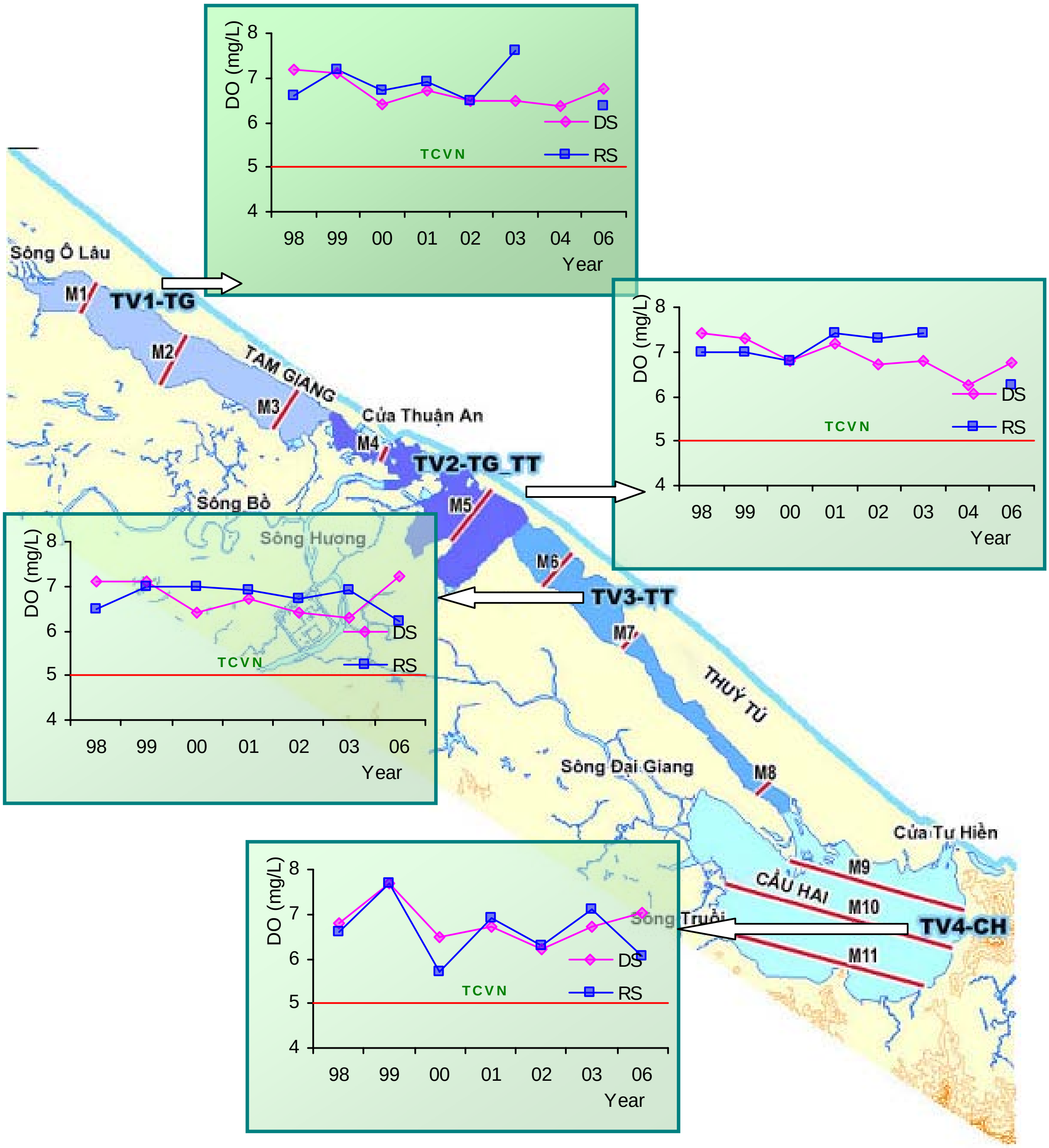

Figure 27. Temporal and spatial change of DO in 4 major areas of the lagoon (1998 – 2006)

Data source (monthly average data):

Year 1998 – 2001 (NPC, 2003) [38]

Year 2002: From January to December (NPC, 2003) [38]; from August to November (Ton That Phap et al., 2003) [8,31]

Year 2003: From January to May (NPC, 2003); from March to June and from October to November (Ton That Phap et al., 2003.) [8,31]

Year 2004: From February to May (Nguyen Hoai Son, 2004)

Year 2006: From February to May and July (Tran Van Hai, 2006) [18]; April, May, August and November (IMOLA, 2006).

3.4.2. Increase in nutrient level

Trends of nutrient concentration in the lagoon water were the same as for organic pollution discussed above (refer to the change of nitrate and phosphate levels at four sub-areas during the period 1998 to 2006 presented in *Figures 28 and 29*). Although, the nitrate (NO_3) concentration was not very high compared with the TCVN 5942-1995 Vietnam Standard for surface water used for multipurposes (N-$NO_3 \leq 15$ mg/L), the total nitrogen (TN) level in several areas of the lagoon (over 1 mg/L) is higher than that of American Standard (TN < 0.9 mg/L), Chinese Standard (TN < 0.5 – 1 mg/L) and Japanese Standard (TN < 0.03 – 0.05 mg/L) applied for coastal aquatic life conservation [8,38,22]. The average concentration of P-PO_4 in the lagoon water (0.01 – 0.03 mg/L) was enough to promote the phytoplankton growth as well as eutrophication [42].

"Eutrophication is an accelerated growth of algae on higher forms of plant life caused by the enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus and inducing an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned" [42]. Under eutrophic conditions, phytoplankton over-growth (including toxic algae) sometimes causes undesirable "algae bloom" phenomena, gradually leading to degradation of biodiversity and damage to aquatic life and other animals [42]. Eutrophication is clearly a concern for the lagoon ecosystem. Eutrophication can increase the risk of oxygen depletion at the bottom of the lagoon which adversely impacts on benthic biota. In addition, toxic algae growth under eutrophic conditions can be a threat to the health of aquatic animals in the lagoon and humans consuming them.

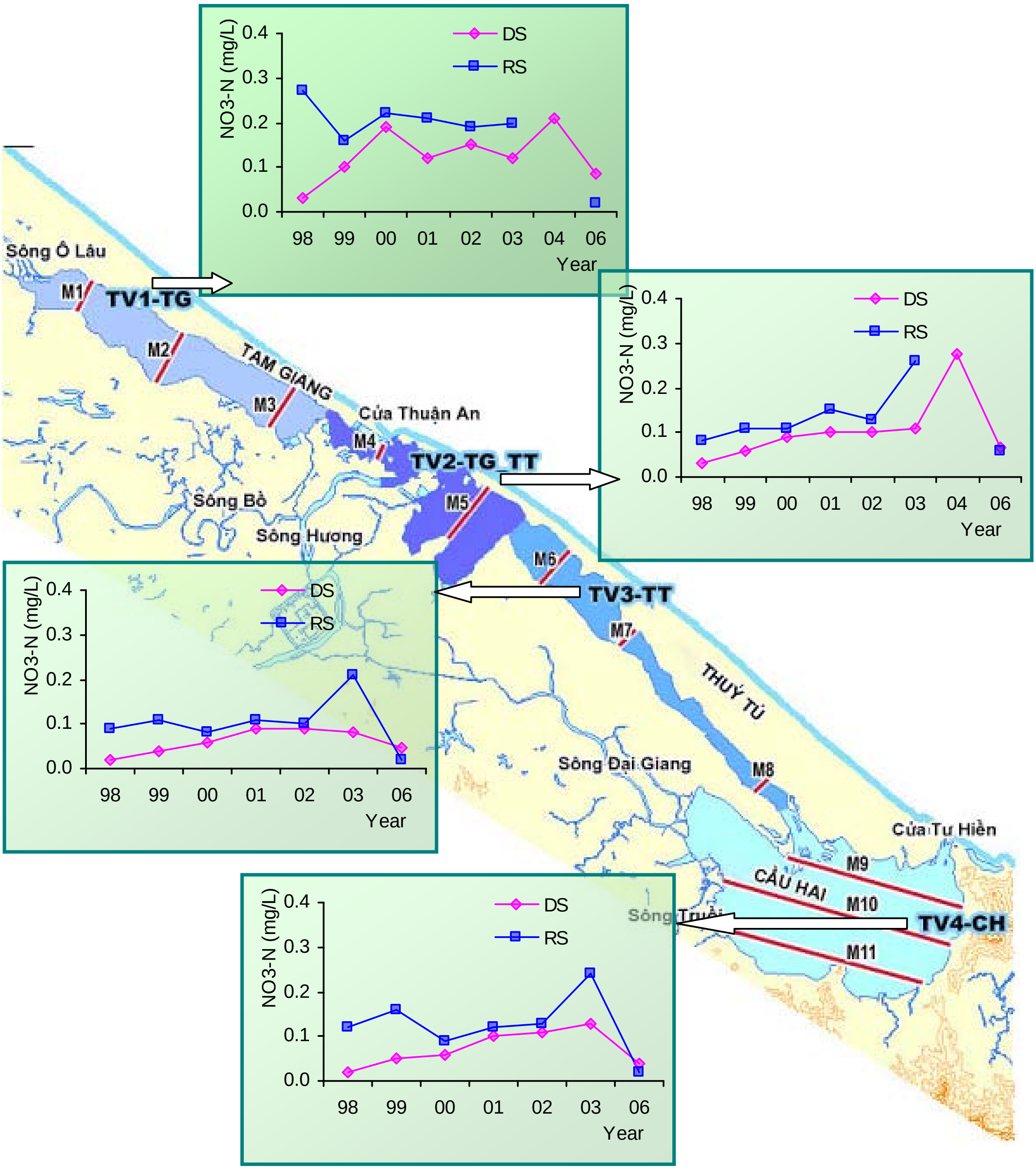

Figure 28. *Nitrate variation of Tam Giang – Cau Hai lagoon*

Data source (monthly average data):

Year 1998 – 2001 (NPC, 2003) [38]

Year 2002: From January to December (NPC, 2003) [38]; from August to November (Ton That Phap et al., 2003) [8,31]

Year 2003: From January to May (NPC, 2003); from March to June and from October to November (Ton That Phap et al., 2003.) [8,31]

Year 2004: From February to May (Nguyen Hoai Son, 2004)

Year 2006: From February to May and July (Tran Van Hai, 2006) [18]; April, May, August and November (IMOLA, 2006).

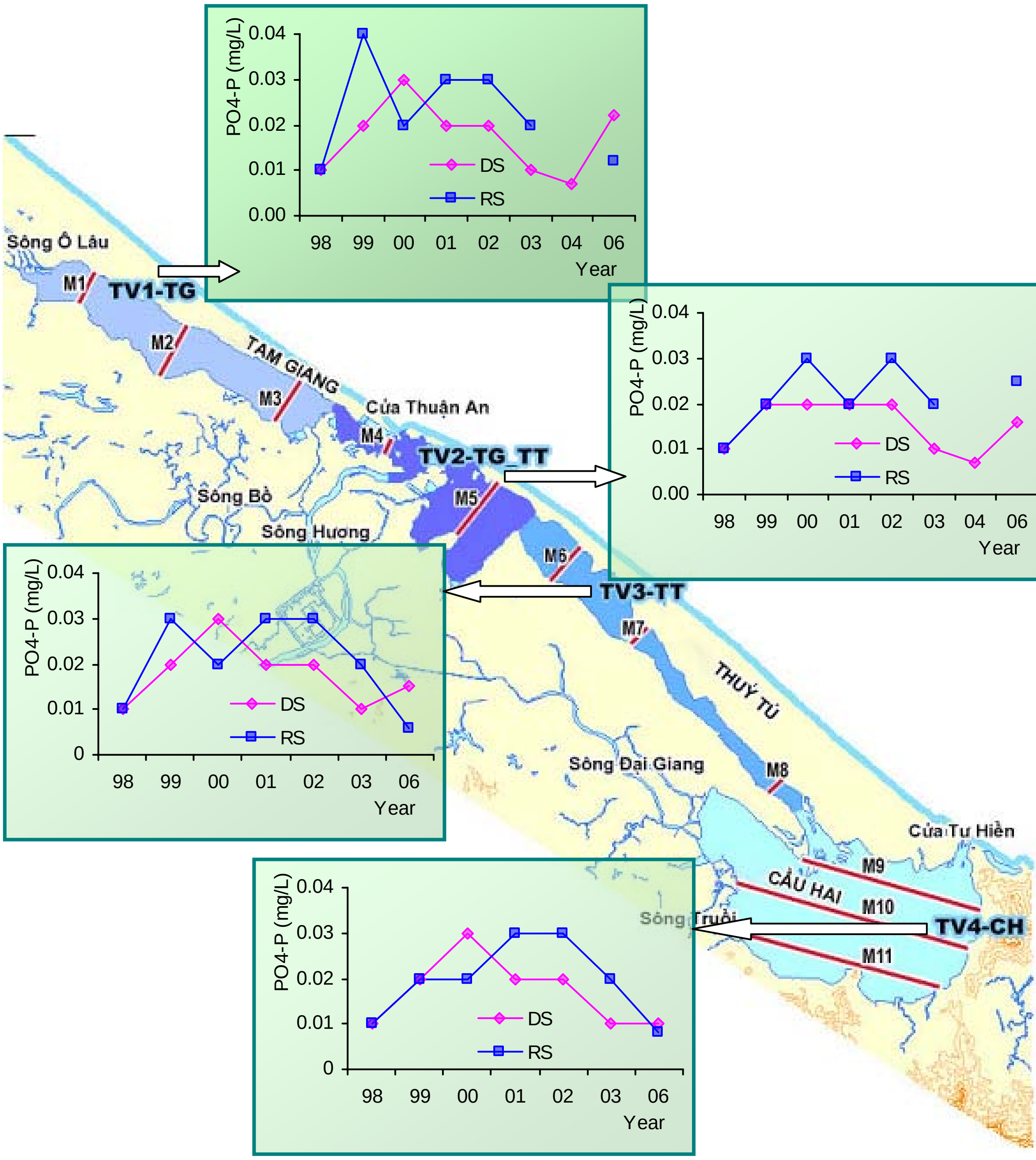

Figure 29. *Phosphate variation of Tam Giang – Cau Hai lagoon*

Data source (monthly average data):

Year 1998 – 2001 (NPC, 2003) [38]

Year 2002: From January to December (NPC, 2003) [38]; from August to November (Ton That Phap et al., 2003) [8,31]

Year 2003: From January to May (NPC, 2003); from March to June and from October to November (Ton That Phap et al., 2003.) [8,31]

Year 2004: From February to May (Nguyen Hoai Son, 2004)

Year 2006: From February to May and July (Tran Van Hai, 2006) [18]; April, May, August and November (IMOLA, 2006).

Two major nutrients are necessary for the development of aquatic life: nitrogen (N) and phosphorus (P). A third one, silicon (Si), is necessary for the development of diatoms. During eutrophication, the concentration of nutrients in the water changes. In some cases one out of the three nutrients may be totally bound to the aquatic life and will not be available for further growth of algae. This nutrient is then called the key/limiting factor. The ratio of nitrogen to phosphorus compounds (TN:TP) in a water body is an important factor determining which of the two elements will be the limiting factor, and consequently which one has to be controlled in order to reduce a bloom. According to WHO (2002) [42], P is the limiting factor if the TN:TP ratio in estuary/coastal waters is over 10.

In the lagoon, the TN:TP ratio in the water ranges between 5 – 65 and is usually greater than 10. It means that the factor limiting lagoon eutrophication in most of the months of the year was found to be phosphorus. Increases in N and P concentration have promoted rapid growth of phytoplankton, especially in the rainy season due to erosion and runoff from farmland and aquaculture discharges. This was evidenced by the increase in phytoplankton biomass (in term of chlorophyll-a concentration) and the increasing occurrence of toxic algae observed in the lagoon during the dry season of the period 2000 to 2003 (ICZM, 2003). In fact, toxic phytoplankton species were observed throughout the lagoon, concentrating mainly in the areas of high salinity (Quang Phuoc – Quang An, Thuy Tu and Cau Hai area). High densities of toxic phytoplankton (over 500 cells/L) occurred during 1998 to 2003, and increased after the year 2000 [29,38].

According to Chapman (1992) [4], eutrophication is present if the chlorophyll-a concentration is in the range of 5 to 140 μg/L (1000 μg/L = 1 mg/L). The chlorophyll-a concentration in lagoon in the dry season is in the range of 4 – 131 and 10 – 30 μg/l on the average in both rainy and dry seasons and thus within the range [22]. *Figure 30* below shows that the increase in nitrate (NO_3) concentration (A) coincides with increased chlorophyll-a (phytoplankton) concentration (B) in the water. While the lagoon eutrophication is currently at low levels, as evidenced by moderate levels of chlorophyll-a concentration in the water, eutrophication indicates an increasing nutrient load going into the lagoon and less absorptive capacity of the natural environment.

(A)

(B)

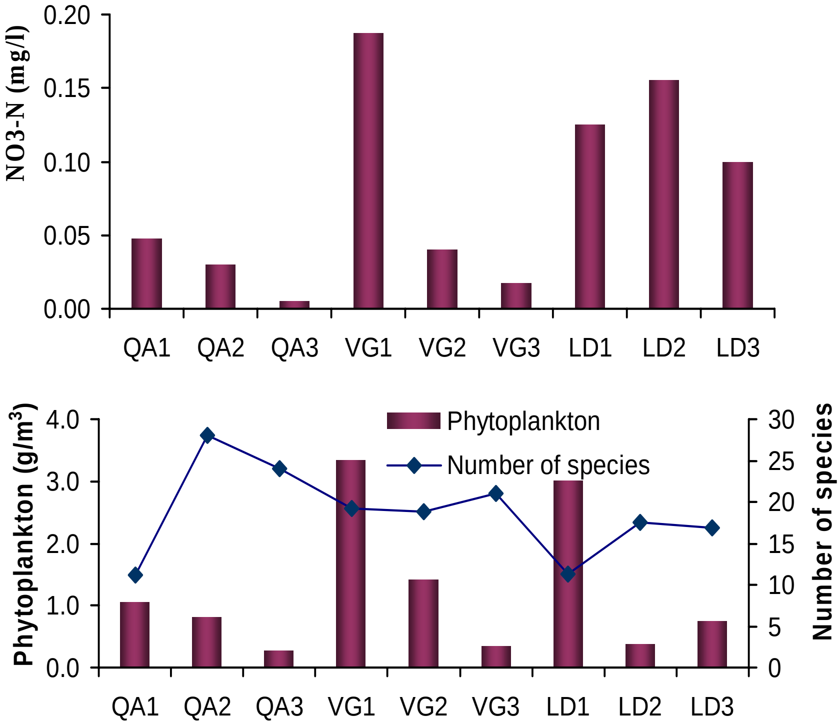

***Figure 30**. Variations of nitrate levels and phytoplankton concentrations (eutrophication),* Source: ICZM, 2004 [8]

Ammonia levels in the lagoon water may also be a problem as it is toxic to aquatic life and can be included in total nitrogen concentrations. Although there is a lack of data on ammonia levels in the lagoon, a recent study found that several of the water samples observed at sites close to crowded aquaculture areas had ammonia concentration levels exceeding the maximum limits of Vietnam Standard 28 TCVN 171:2001 (N-ammonia $\leq$ 0.1 mg/l) [18]. The sources of ammonia might also include the aquaculture and agriculture pollution.

3.4.3. Fecal bacteria pollution

Pathogen pollution, especially fecal bacteria, is one of the main water quality concerns, as it may cause intestinal illnesses for human and animals. To define the presence of fecal bacteria in the water, the coliform group is determined in terms of total coliform and fecal coliform. Total coliform density in the lagoon water exceeded the permitted level of the Vietnam Standard (TCVN 5943-1995) of water quality used for multi-purposes [29,38]. Although the fecal coliform level is not guided by TCVN 5943-1995, there are indications that the lagoon water has been polluted with fecal bacteria (potential cause of diseases for aquatic animals in the lagoon). The fecal bacteria pollution is derived from domestic, municipal and industrial wastes, human sewage and livestock wastes discharged into the lagoon.

3.4.4. Organochlorine pesticides (OCs) in the lagoon sediment

Although the level of OCs in the water is rather low, the OC content in the lagoon sediment (based on dry weight) was rather high in the Tam Giang and Cau Hai area, and especially in the places close to the estuaries of O Lau River and Truoi River, but lower in Thuy Tu area:

- DDTs (total DDTs) content in the lagoon was in the range of 9.8 to 33.4 ppb (n = 27 in the year 2001; N.X. Khoa et al, 2004) and 0.2 to 8.2 ppb (n = 10 in 2005; T.T.V. Thi et al, 2007), and 0.24 to 10.3 ppb (n = 25 in 2006 – 2007 in this study); many of the DDTs levels were higher than that specified in the ISQG (4.48 ppb) and many data in N.X. Khoa's study were even higher than the PEL (16.32 ppb) applied to marine sediment;
- HCHs (total HCHs) content (ranging from 5.56 to 92.4 ppb; n = 10 in 2005; T.T.V. Thi et al, 2007) was 6 to 90 times higher than that of the PEL (0.99 ppb); several levels of aldrin and dieldrin observed by Thi's study in the lagoon (n = 10 in 2005) were 5 to 30 times higher than that of the PEL (4.30 ppb); also, levels of endrin found in several samples (n = 10 in 2005) were about 10 times higher than that of the ISQG (2.67 ppb), but lower than that of the PEL (62.4 ppb). The HCHs contents observed in this study (2006 – 2007) was in the range of 1 – 2 ppb (n = 25).

The high levels of OCs in the lagoon sediment are likely to be adversely effecting the ecosystem, human health via food chains and the quality and productivity of aquatic biota in the lagoon. High bioaccumulation of DDTs in several benthic species was found in the period 1998 to 2001 in rabbitfish (179 ± 52 ppb; n = 25) and local carp (286 ± 82 ppb; n = 25) collected in the Tam Giang – Cau Hai lagoon and in blue mussel (776 ± 190 ppb; n = 65) collected in Lang Co lagoon (Khoa et al, 2004). Although these are preliminary studies only, there should certainly be concerns about the quality of aquatic products as well as the human health implications of consuming them.

As use of OCs in agriculture has been prohibited in Vietnam since 1995, a decreasing trend in the OCs level in the lagoon water and sediment can be observed from the above data: decrease in DDTs level from 9.8 - 33.4 ppb in 2001 down to 0.2 – 10.3 ppb in the period of 2005 and 2007. In spite of that, DDTs are still being used for malaria prevention and illegally for agriculture by many local farmers due to entrenched habits and the high effectiveness of DDTs. As such, concerns about the adverse effects on organisms and human health remain.

3.4.5. Heavy metals (HMs)

In general, the level of HMs in the lagoon sediment was much lower than that of ISQG and PEL (NPC, 2003; N.V. Cu and Mauro Frignani, 2005). However, copper (Cu) levels found in a few sediment samples was higher than that of the ISQG (18,700 ppb) and the PEL (108,000 ppb). The reasons for this are unclear, as there are no industrial wastewaters containing much copper discharged into the lagoon, except a small copper-casting enterprise located on the bank of Loi Nong River, a branch of Huong River, running into Cau Hai lagoon. Although there is no research on HMs bioaccumulation in aquatic animals in the lagoon so far, there are possible reasons for concern given their toxicity to organisms in the lagoon and to human health.

Finally, it should be noted that the river flows and associated suspended solids transported into the lagoon are a major source of the OCs and HMs. Due to the lack of data regarding the flows and suspended solids transportation, and a lack of data on the OCs and HMs in the river sediment, it is difficult to estimate the loads of the OCs and HMs discharged from the rivers and run-off into the lagoon. However, several data sets of the OCs and HMs in Huong River water (Hop et al., 2006 [21]) indicate that levels in the river water are as low as that in the lagoon.

4. CONCLUSIONS

Most of water quality parameters of Tam Giang – Cau Hai lagoon such as temperature, pH, DO, BOD_5, ammonia, toxic metals (Cu, Pb, Zn and Cd) and OCs (DDTs and HCHs) met the requirement of Vietnam standard TCVN 5943-1995 applied to the coastal water used for aquaculture and other purposes.

Although PO4 and NO3 concentration in the lagoon water was low (N-NO3 < 0.26 mg/L and P-PO4 < 0.10 mg/L), TN concentrations were higher than 1 mg/L in several sites. The TN concentrations were potential to cause eutrophication, especially in the dry season. The results of chlorophyll-a in the lagoon water (higher than 5 μg/L in many sites in the dry season) were also an evidence to affirmed eutrophication in the lagoon. Based on the ratio TN/TP in water column, phosphorus was identified as a main limiting factor of eutrophication in the lagoon.

In Thuy Tu and Cau Hai area, water quality parameters such as temperature, pH and especially salinity (stations from F to L) were quite suitable for black tiger shrimp culture in the dry season. However, uncontrolled aquacuture development caused disavantages to the lagoon environment such as increase in organic and baterial pollution, and eutrophic status.

In this study, the lagoon sediment organic matters were taken into consideration in the first time. The results obtained allow identifying some new indicators of benthic eutrophication, which is independently from the putative trophic state of the water column, and gathering a good assessment of the trophic conditions in the sediment. Both the proxies of primary production and the measurement of the detrital fractions of sediment organic matter also allows distinguishing clearly those systems characterised by eutrophic and even hypertrophic conditions. The sediment of the whole lagoon was in the eutrophic state .

Although concentration of toxic chemicals (OCs and toxic metals) in the lagoon water was fairly low, HCHs level in the lagoon sediment was rather high in several sites (near Thuan An inlets), and thus that can cause adverse effects on aquatic organism in the lagoon ecosystem. Toxic metals concentration in the lagoon sediment was, in general, lower than the levels of ISQG and PEL applied to the marine sediment. However, Cd and Cu content in the lagoon sediment in several sites was higher than the levels of ISQG.

Most of the water quality parameters in the canals adjacent to the aquaculture ponds met the requirement of the Vietnam Standard TCVN5943-1995 applied to the coastal water used for aquaculture and 28 TCN 171:2001 applied to intensive culture of black tiger shrimp. However, aquaculture activities need to be controled in order to mitigate environmental problems in the lagoon.

5. PROPOSED FOLLOW-UP ACTIONS

Bold and drastic management measures are needed to halt the decline and degradation of natural resources in the lagoon. The lagoon resources are clearly being over-exploited at well above the sustainable carrying capacity. However, in the coastal zone, few options for alternative livelihoods not dependent on the lagoon resources exist. Many changes that are necessary would have short-term impacts on local livelihoods and poverty while not making the changes will have serious long-term implications for both the environment and those who depend on it. Overall, a shift in focus is needed from managing the lagoon as an aquaculture resource to managing it as a critical and threatened environmental resource with many different values.

Based on the environmental issues analysed above and refered to the past studies, and with the aim of contributing to improvement of the lagoon environment and reducing poverty as soon as possible, several necessary priority actions have been proposed.

1) **Implement the action plans outlined in the Integrated Coastal Zone Management Strategy** that was endorsed by the Provincial People's Committee in 2004, particularly the priority action plans. The detailed action plans developed as part of the ICZM Strategy present good ways to develop the economy and protect the environment of the coastal zone. However, as they require significant time, funds, institutional strengthening and cooperation and collaboration of stakeholders to implement, these plans have not progressed well to date. Efforts are needed to address the reasons for this lack of progress.

2) **Create efficient and feasible community-based models of solid waste collection and treatment in the lagoon region**, including (i) creation of a community-based collection network at commune level (from households to hamlets and commune); (ii) research to select and apply suitable solutions to treatment of solid wastes collected such as composting and/ or land fills; (iii) improvement of collection and treatment of animal husbandry and sewage wastes such as use of biogas models; and (iv) issue of suitable regulations to assure success of the models. Of course, these efforts will not be successful if no synchronous solutions to control pollution of the rivers flowing into the lagoon such as waste collection and treatment and prevention of deforestation upstream of the rivers exist .

3) **Establish an agency responsible for lagoon management.** Due to the socio-economic and environmental importance of the lagoon, it is necessary to establish an administrative agency with clear management responsibilities over the lagoon.

The activities of this agency must assure more efficient management of the lagoon including aquaculture and exploitation of natural resources, environmental monitoring and database storage etc. This represents a move towards an 'area-based' management structure rather than the current sector-based system and would facilitate more integrated management. It should also facilitate proper consideration of environmental values and cumulative impacts on the environment of the different activities and uses. Such an agency would coordinate research and development in the lagoon area and develop a set of objectives that includes environmental targets.

4) **Assessment of the lagoon-ecosystem carrying capacity and zoning of the lagoon for different uses.** Assessment of the ecosystem carrying capacity will be helpful to analyse impacts of pressures including aquacultrue, agriculture, urban and industrial activities on the lagoon to provide decision-makers with more insights into the possible consequences of development decisions on the lagoon. Based on scientific analysis of existing data of the water quality, biodiversity and hydrology, zoning of the lagoon for different uses - such as protected areas, aquaculture areas, nursery grounds and fishing grounds (using mobile and immobile gears) etc - will facilitate appropriate exploitation of the lagoon resources and development of ecological tourism in the region. A comprehensive re-structuring and re-arrangement of existing aquaculture and fishing operations is needed.

5) **Establish a feasible environment monitoring program and GIS database for the lagoon and main rivers environment**, consisting of (i) monitoring plans including sites and frequency; (ii) sensitive indicators (water quality and biological indicators, focusing on organic content, nutrients, bacteria pollution indicators, organichlorine pesticides in the sediment and several bioindicators) need to be observed as must monitoring methods; (iii) sensible standards/guidelines for each indicator that can be applied to check the state and change of indicators; (iv) laboratories responsible for the monitoring program and analysis of results; (v) an office and method for data storage based on GIS and data interpretation; (vi) data access, sharing and communication and (vii) formulation of environment advice to the provincial leadership. The database will

provide users with data and information about the state of the lagoon environment and trends and changes in the lagoon as well as upstream areas of the main rivers. Links with the universities and research institutions should be improved and institutionalised to ensure the relevance, efficiency and coordination of research efforts. Practical information should be generated and information interpretation should be improved.

6) **Improve environmental awareness.** Improvement of environmental awareness should be more efficiently implemented by a bottom-up approach instead of top-down methods as done at present. This should occur at all levels including government agencies as part of a systematic campaign including, for example, initiatives to improve awareness through schools. Improved environmental awareness will assist the effective implementation of regulations and guidelines.

7) **Community-based management of aquaculture** is necessary given the current ineffectiveness of government regulations and the limited capacity of government management agencies. Support to the Aquaculture Groups and Fisheries Associations established by previous community-based initiatives should be provided to improve management capacity and reduce environmental impacts. Support should be systematic and include funding support for management of aquaculture and fisheries areas, training in management and facilitation and extension services. Training and education about environmental issues and current regulations and guidelines is also a priority. Dividing the lagoon into smaller management areas with a community-based management unit should facilitate improved management, dissemination of information and direct provision of extension and other support to the local people.

8) **Protected areas managed for the conservation of the environment should be established** to conserve biodiversity and improve the restorative ability of the lagoon ecosystem. The reduction in areas accessible for fishing and other activities will be difficult in the short-term, especially for poor households, so livelihood support packages must go hand in hand with the establishment of protected areas.

9) **Research** into the human health issues identified in this study, such as ground-water quality and management, and OC levels in the sediment and the food chain is also recommended.

10) **Implement a pilot model of sustainable aquaculture focusing on improved enviornmental management in brackish shrimp culture at the lagoon**, including (i) training of aquaculture farmers and provision of equipment for water quality measurement and management during the farming process; (ii) appropriate treatment of sediment during preparation of the culture ponds; (iii) training in medium-density and/ or high-density shrimp culture techniques; (iv) efficient oganization of community-based management, based on Aquaculture Groups existing at the commune level; and (v) improvement of environmental awareness of the local people, especially aquaculture households. As a second phase, rearrangement of shrimp culture ponds and drainage channels is needed to facilitate best practices, especially water quality control by creating ponds for pre- and post-treatment of water. This model can be enlarged in other communities and will facilitate good practice in aquaculture and ultimately poverty reduction.

Although these are not easy tasks, such tasks require urgent attention to facilitate the recovery of the ecosystem and the natural resources in the lagoon and avoid the consequences of continuing decline and degradation of environmental resources and the associated implications for poverty.

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Appendix A1. ANALYSIS RESULTS OF TAM GIANG LAGOON WATER AND SEDIMENT SAMPLES (IMOLA PROJECT)

April – 2006

Parameter	Layer	Site/Station														
		A			**B**			**C**			**D**			**E**		
		1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***
Temperature (^{o}C)		27.8	28.3	28.9	27.9	28.4	28.9	26.1	23.1	26.7	26.9	27.4	27.3	27.0	27.8	28.2
pH		6.7	7.1	7.6	7.5	7.3	8.3	7.3	7.4	7.6	7.8	7.8	7.7	8.1	7.5	7.7
Salinity ($^0/_{00}$)		1.0	1.0	1.0	1.0	1.0	1.0	5.0	4.0	4.0	15.0	15.5	15.5	27.5	8.0	5.0
Transparency (cm)		50	100	70	90	110	40	120	130	70	100	180	140	250	100	80
DO (mg/l)		7.2	7.0	7.3	7.1	7.2	7.3	6.6	6.2	6.2	6.1	6.7	6.4	7.0	6.7	6.8
BOD5 (mg/l)	Surface	0.8	0.6	0.8	0.4	0.5	0.4	0.3	0.6	0.7	1.9	0.8	1.0	0.4	0.5	0.7
COD (mg/l)	Surface	5	5	4	6	5	7	7	7	8	5	4	6	4	5	5
Chlorophyll a(µg/l)	Surface	0.9	1.2	0.5	0.6	0.8	0.5	0.5	0.7	0.9	2.1	1.5	1.1	0.9	0.4	0.5
Total coliform (MPN/100ml)	Surface	1700	1100	1100	1100	750	0	540	450	450	2400	1700	150	0	5400	750
Fecal coliform (MPN/100ml)	Surface	1100	500	150	500	410	0	410	410	210	1100	900	50	0	2300	110
NH4/NH3-N (mg/l)	Surface	0.04	0.05	0.05	0.06	0.08	0.07	0.03	0.05	0.07	0.02	0.03	0.02	< 0.02	0.04	0.05
NO2-N (mg/l)	Surface	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
NO3-N (mg/l)	Surface	0.24	0.17	0.23	0.26	0.25	0.13	0.09	0.14	<0.05	0.05	0.09	0.06	0.05	0.13	0.12
	Bottom							0.15				0.04		0.08		
PO4-P (mg/l)	Surface	< 0.01	0.03	0.03	< 0.01	0.02	< 0.01	0.05	0.02	0.03	0.04	0.03	0.03	0.03	0.03	0.03
	Bottom							0.04				< 0.01		< 0.01		
TN (mg/l)	Surface	1.17	1.51	0.62	1.03	0.59	0.89	1.15	1.07	0.53	0.96	0.18	0.15	0.55	1.26	0.77
	Bottom							0.94				1.15		0.09		
TP (mg/l)	Surface	0.05	0.05	0.11	0.05	0.07	0.03	0.09	0.06	0.07	0.09	0.06	0.07	0.06	0.07	0.07
	Bottom							0.09				0.04		0.03		
Copper	Water (µg/l)	0.4			0.72			1.3			1.4			0.76		
	Sediment (µg/kg)	16640			12240			21800			3340			31800		

<table>
<tr><th rowspan="3">Parameter</th><th rowspan="3">Layer</th><th colspan="15">Site/Station</th></tr>
<tr><th colspan="3">A</th><th colspan="3">B</th><th colspan="3">C</th><th colspan="3">D</th><th colspan="3">E</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th></tr>
<tr><td rowspan="2">Lead</td><td>Water (µg/l)</td><td colspan="3">0.25</td><td colspan="3">0.30</td><td colspan="3">0.45</td><td colspan="3">0.26</td><td colspan="3">0.27</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">21300</td><td colspan="3">14000</td><td colspan="3">14400</td><td colspan="3">6970</td><td colspan="3">16400</td></tr>
<tr><td rowspan="2">Cadmium</td><td>Water (µg/l)</td><td colspan="3">0.05</td><td colspan="3">0.03</td><td colspan="3">0.08</td><td colspan="3">0.05</td><td colspan="3">0.03</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">250</td><td colspan="3">200</td><td colspan="3">930</td><td colspan="3">280</td><td colspan="3">350</td></tr>
<tr><td rowspan="2">Zinc</td><td>Water (µg/l)</td><td colspan="3">2.76</td><td colspan="3">1.5</td><td colspan="3">3.36</td><td colspan="3">2.88</td><td colspan="3">3.72</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">60000</td><td colspan="3">10600</td><td colspan="3">16200</td><td colspan="3">10200</td><td colspan="3">10300</td></tr>
<tr><td rowspan="2">p,p’-DDE</td><td>Water (µg/l)</td><td colspan="15"><MDL</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">0.97</td><td colspan="3">0.45</td><td colspan="3">0.19</td><td colspan="3">0.63</td><td colspan="3">0.63</td></tr>
<tr><td rowspan="2">p,p’-DDD</td><td>Water (µg/l)</td><td colspan="15"><MDL</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">0.77</td><td colspan="3">< 0.15</td><td colspan="3">< 0.15</td><td colspan="3">< 0.15</td><td colspan="3">0.19</td></tr>
<tr><td rowspan="2">p,p’-DDT</td><td>Water (µg/l)</td><td colspan="15"><MDL</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">2.01</td><td colspan="3">< 0.15</td><td colspan="3">0.65</td><td colspan="3">0.70</td><td colspan="3">1.81</td></tr>
<tr><td rowspan="2">∑ DDTs</td><td>Water (µg/l)</td><td colspan="15">< MDL</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">3.75</td><td colspan="3">0.45</td><td colspan="3">0.84</td><td colspan="3">1.33</td><td colspan="3">2.63</td></tr>
<tr><td rowspan="2">α-HCH</td><td>Water (µg/l)</td><td colspan="15"><MDL</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">0.42</td><td colspan="3">0.36</td><td colspan="3">0.36</td><td colspan="3">0.44</td><td colspan="3">0.21</td></tr>
<tr><td rowspan="2">β-HCH</td><td>Water (µg/l)</td><td colspan="15"><MDL</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">0.19</td><td colspan="3">< 0.05</td><td colspan="3"><0.05</td><td colspan="3">0.08</td><td colspan="3">< 0.05</td></tr>
<tr><td rowspan="2">δ-HCH</td><td>Water (µg/l)</td><td colspan="15">2.39</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">2.13</td><td colspan="3">1.22</td><td colspan="3">0.52</td><td colspan="3">1.55</td><td colspan="3">0.05</td></tr>
<tr><td rowspan="2">∑ HCHs</td><td>Water (µg/l)</td><td colspan="15">2.39</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">2.74</td><td colspan="3">1.58</td><td colspan="3">0.88</td><td colspan="3">2.07</td><td colspan="3">0.26</td></tr>
</table>

$\mu g.kg^{-1}$ dw (dry weight)

MDL: Method Detection Limit (Copper: 0.01 µg/l; Lead: 0.25 µg/l; Cadmium: 0.01 µg/l; Zinc: 0.25 µg/l: DDTs: 0.0005 µg/l; HCHs: 0.0002 µg/l)

Appendix A2. ANALYSIS RESULTS OF TAM GIANG LAGOON WATER AND SEDIMENT SAMPLES (IMOLA PROJECT)

May - 2006

Parameter	Layer	Site/Station														
		A			**B**			**C**			**D**			**E**		
		1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***
Temperature (^oC)		28.5	28.4	31.3	31.5	29.9	31.6	31.7	31.5	32.4	30.5	30.5	31.2	29.0	28.1	31.0
pH		6.5	6.2	6.5	6.9	8.2	9.0	8.2	8.7	8.3	8.0	8.1	8.1	8.2	8.2	8.1
Salinity ($^0/_{00}$)		1.0	1.0	1.0	10.0	14.5	10.0	14.5	13.0	14.5	18.0	18.0	17.0	30.0	31.5	13.5
Transparency (cm)		60	50	100	100	120	100	180	100	70	100	120	100	200	150	110
DO (mg/l)		5.2	5.2	7.3	7.7	7.5	8.3	7.5	7.4	7.6	6.1	6.1	6.2	7.1	7.5	7.5
BOD5 (mg/l)	Surface	1.3	0.8	0.9	1.3	1.5	0.7	1.8	1.6	2.3	1.0	0.9	0.9	0.6	0.3	0.4
COD (mg/l)	Surface	5	4	5	7	7	8	8	7	7	5	4	5	5	5	4
Chlorophyll a(µg/l)	Surface	1.9	1.4	0.5	2.6	8.2	0.6	3.5	3.3	2.6	4.2	4.3	5.9	1.1	1.0	0.2
Total coliform (MPN/100ml)	Surface	2800	46000	2700	46000	>240000	1500	21000	15000	1100	2000	2000	2800	1100	>240000	2800
Fecal coliform (MPN/100ml)	Surface	300	2800	700	0	1500	600	2800	400	400	1100	300	1100	300	2000	1100
NH4/NH3-N (mg/l)	Surface	0.06	<0.02	0.04	0.03	0.04	0.02	0.02	0.02	0.05	<0.02	0.06	0.04	0.02	0.02	0.02
NO2-N (mg/l)	Surface	0.003	0.005	<0.002	<0.002	0.004	<0.002	<0.002	0.002	0.003	<0.002	<0.002	<0.002	<0.002	<0.002	0.007
NO3-N (mg/l)	Surface	<0.05	<0.05	<0.05	0.07	0.05	0.05	0.06	0.06	0.06	0.07	0.06	0.06	0.07	0.07	0.21
	Bottom					0.06		0.13						0.09		0.17
PO4-P (mg/l)	Surface	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.02	<0.01	<0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01
	Bottom					<0.01		< 0.01						<0.01		<0.01
TN (mg/l)	Surface	<0.05	<0.05	0.06	1.51	0.79	0.75	0.99	0.83	1.07	1.31	1.88	1.74	1.08	1.64	0.92
	Bottom					0.81		0.64						1.03		0.53
TP (mg/l)	Surface	0.02	0.04	0.03	0.03	0.07	0.02	0.04	0.04	0.04	0.06	0.05	0.04	0.04	0.03	0.04
	Bottom					0.09		0.04						0.03		0.03
Copper	Water (µg/l)	0.64			0.76			0.94			1.08			1.68		
	Sediment (µg/kg)	8440			6620			21400			1460			129600		

Parameter	Layer	Site/Station				
		A	**B**	**C**	**D**	**E**
		1, 2, 3	***4, 5, 6***	***7, 8, 9***	***10, 11, 12***	***13, 14, 15***
Lead	Water (µg/l)	0.48	0.34	0.28	0.25	0.27
	Sediment (µg/kg)	31500	9640	20300	15300	19100
Cadmium	Water (µg/l)	0.05	0.08	0.04	0.05	0.03
	Sediment (µg/kg)	600	500	670	200	22800
Zinc	Water (µg/l)	3.48	2.76	3.00	3.84	3.66
	Sediment (µg/kg)	30180	47340	24840	31260	105600
p,p’-DDE	Water (µg/l)	< MDL				
	Sediment (µg/kg)	0.54	0.74	1.10	0.71	0.77
p,p’-DDD	Water (µg/l)	< MDL				
	Sediment (µg/kg)	< 0.15	< 0.15	4.11	1.36	2.47
p,p’-DDT	Water (µg/l)	< MDL				
	Sediment (µg/kg)	< 0.15	< 0.15	0.55	< 0.15	1.81
∑ DDTs	Water (µg/l)	< MDL				
	Sediment (µg/kg)	0.54	0.74	5.76	2.07	5.05
α-HCH	Water (µg/l)	< MDL				
	Sediment (µg/kg)	< 0.05	0.24	0.31	0.26	0.21
β-HCH	Water (µg/l)	< MDL				
	Sediment (µg/kg)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
δ-HCH	Water (µg/l)	0.04				
	Sediment (µg/kg)	< 0.05	< 0.05	0.06	2.70	0.87
∑ HCHs	Water (µg/l)	0.04				
	Sediment (µg/kg)	< 0.05	0.24	0.37	2.96	1.08

µg.kg $^{-1}$ *dw (dry weight)*

MDL: Method Detection Limit (Copper: 0.01 µg/l; Lead: 0.25 µg/l; Cadmium: 0.01 µg/l; Zinc: 0.25 µg/l: DDTs: 0.0005 µg/l; HCHs: 0.0002 µg/l)

Appendix A3. ANALYSIS RESULTS OF TAM GIANG LAGOON WATER AND SEDIMENT SAMPLES (IMOLA PROJECT)

August - 2006

Parameter	Layer	Site/Station														
		A			**B**			**C**			**D**			**E**		
		1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***
Temperature (^oC)		30.3	31.2	31.5	31.5	29.1	32.0	25.6	30.8	32.4	29.8	29.2	29.9	30.3	30.0	30.2
pH		5.5	5.7	6.1	6.4	6.3	8.2	6.4	7.5	7.8	7.0	7.1	7.0	7.8	6.5	6.7
Salinity ($^0/_{00}$)		<1	<1	<1	<1	<1	<1	<1	<1	1.5	<1	1.5	1.5	2.0	2.0	<1
Transparency (cm)											80	85	100	100	75	70
DO (mg/l)		5.5	6.8	6.5	6.7	6.6	7.2	6.3	7.0	7.2	6.5	6.4		7.2	6.1	6.3
BOD5 (mg/l)	Surface	0.9	1.0	0.8	0.4	0.5	0.4	0.6	1.2	1.6	2.1	2.8	2.2	0.8	1.0	0.7
COD (mg/l)	Surface	8	11	12	10	9	8	9	6	7	5	6	12	11	6	7
Chlorophyll a(μg/l)	Surface	2.0	2.5	6.8	5.1	4.1	2.3	7.0	2.2	8.0	9.2	5.4	8.3	4.8	2.6	5.6
Total coliform (MPN/100ml)	Surface	9300	2400	900	400	110000	400	15000	400	2100	1500	1100	4600	15000	21000	7500
Fecal coliform (MPN/100ml)	Surface	400	700	400	200	2000	200	700	200	700	700	700	400	700	1100	400
NH4/NH3-N (mg/l)	Surface	0.08	0.07	0.06	0.03	0.10	0.02	0.05	0.04	0.05	0.04	0.06	0.04	0.04	0.06	0.07
NO3-N (mg/l)	Surface	0.09	0.15	0.12	0.19	0.20	<0.05	0.16	0.05	<0.05	0.17	0.09	0.08	0.10	0.23	0.22
	Bottom							0.20						<0.05		
PO4-P (mg/l)	Surface	0.03	0.02	0.02	0.09	0.10	0.01	0.02	0.01	0.06	0.08	0.05	0.08	0.01	0.01	0.01
	Bottom							0.04						0.02		
TN (mg/l)	Surface	0.31	0.35	0.24	0.40	0.36	0.16	0.32	0.13	0.18	0.44	0.23	0.20	0.24	0.37	0.35
	Bottom							0.25						2.69		
TP (mg/l)	Surface	0.07	0.06	0.08	0.12	0.24	0.05	0.08	0.04	0.08	0.12	0.09	0.14	0.06	0.04	0.04
	Bottom							0.10						0.05		
Copper	Water (μg/l)	1.33			0.85			1.23			2.41			4.29		
	Sediment (μg/kg)	11722			10266			9608			8480			24260		

<table>
<tr><th rowspan="3">Parameter</th><th rowspan="3">Layer</th><th colspan="15">Site/Station</th></tr>
<tr><th colspan="3">A</th><th colspan="3">B</th><th colspan="3">C</th><th colspan="3">D</th><th colspan="3">E</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th></tr>
<tr><td rowspan="2">Lead</td><td>Water (µg/l)</td><td colspan="3">0.41</td><td colspan="3">0.36</td><td colspan="3">0.68</td><td colspan="3">0.74</td><td colspan="3">3.65</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">28509</td><td colspan="3">19032</td><td colspan="3">19325</td><td colspan="3">7029</td><td colspan="3">17322</td></tr>
<tr><td rowspan="2">Cadmium</td><td>Water (µg/l)</td><td colspan="3">0.16</td><td colspan="3">0.06</td><td colspan="3">0.30</td><td colspan="3">0.15</td><td colspan="3">0.45</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">1089</td><td colspan="3">178</td><td colspan="3">722</td><td colspan="3">256</td><td colspan="3">322</td></tr>
<tr><td rowspan="2">Zinc</td><td>Water (µg/l)</td><td colspan="3">3.05</td><td colspan="3">1.46</td><td colspan="3">1.45</td><td colspan="3">1.53</td><td colspan="3">0.83</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">75600</td><td colspan="3">48600</td><td colspan="3">75600</td><td colspan="3">58500</td><td colspan="3">71100</td></tr>
<tr><td rowspan="2">p,p’-DDE</td><td>Water (µg/l)</td><td colspan="15">< MDL</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">0.64</td><td colspan="3">0.94</td><td colspan="3">1.10</td><td colspan="3">0.82</td><td colspan="3">0.95</td></tr>
<tr><td rowspan="2">p,p’-DDD</td><td>Water (µg/l)</td><td colspan="15">< MDL</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">0.25</td><td colspan="3">0.30</td><td colspan="3">4.50</td><td colspan="3">1.80</td><td colspan="3">2.90</td></tr>
<tr><td rowspan="2">p,p’-DDT</td><td>Water (µg/l)</td><td colspan="15">< MDL</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">0.20</td><td colspan="3">0.25</td><td colspan="3">0.75</td><td colspan="3">0.35</td><td colspan="3">1.90</td></tr>
<tr><td rowspan="2">∑ DDTs</td><td>Water (µg/l)</td><td colspan="15">< MDL</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">1.09</td><td colspan="3">1.49</td><td colspan="3">6.35</td><td colspan="3">2.97</td><td colspan="3">5.75</td></tr>
<tr><td rowspan="2">α-HCH</td><td>Water (µg/l)</td><td colspan="15">< MDL</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">0.15</td><td colspan="3">0.44</td><td colspan="3">0.38</td><td colspan="3">0.30</td><td colspan="3">0.35</td></tr>
<tr><td rowspan="2">β-HCH</td><td>Water (µg/l)</td><td colspan="15">< MDL</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">< 0.05</td><td colspan="3">< 0.05</td><td colspan="3">< 0.05</td><td colspan="3">< 0.05</td><td colspan="3">< 0.05</td></tr>
<tr><td rowspan="2">δ-HCH</td><td>Water (µg/l)</td><td colspan="15">2.50</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">< 0.05</td><td colspan="3">< 0.05</td><td colspan="3">0.26</td><td colspan="3">1.70</td><td colspan="3">1.20</td></tr>
<tr><td rowspan="2">∑ HCHs</td><td>Water (µg/l)</td><td colspan="15">2.50</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">0.15</td><td colspan="3">0.44</td><td colspan="3">0.64</td><td colspan="3">2.00</td><td colspan="3">1.55</td></tr>
</table>

µg.kg^{-1} dw (dry weight)

MDL: Method Detection Limit (Copper: 0.01 µg/l; Lead: 0.25 µg/l; Cadmium: 0.01 µg/l; Zinc: 0.25 µg/l: DDTs: 0.0005 µg/l; HCHs: 0.0002 µg/l)

Appendix A4. ANALYSIS RESULTS OF TAM GIANG LAGOON WATER AND SEDIMENT SAMPLES (IMOLA PROJECT)

November - 2006

Parameter	Layer	Site/Station														
		A			**B**			**C**			**D**			**E**		
		1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***
Temperature (^oC)		30.9	31.1	31.7	30.6	31.0	31.2	30.2	30.2	30.9	29.9	29.9	30.9	28.9	29.6	29.0
pH		7.5	8.6	8.7	7.6	7.9	8.2	7.6	6.9	7.3	8.0	8.1	7.8	7.8	7.2	7.8
Salinity ($^0/_{00}$)		<1	<1	1.0	1.5	2.0	<1	3.5	1.0	1.0	9.0	10.5	8.0	19.5	2.5	5.5
Transparency (cm)		-	-	-	100	120	80	150	120	100	120	-	-	150	120	130
DO (mg/l)		6.2	6.3	6.4	6.3	6.2	6.3	6.5	6.4	6.5	6.2	6.5	6.4	6.3	6.5	6.4
BOD5 (mg/l)	Surface	0.4	0.5	0.8	0.4	0.3	0.6	0.3	0.4	0.5	0.7	0.6	0.6	0.6	0.4	0.4
COD (mg/l)	Surface	5	5	6	6	5	5	7	7	8	7	6	6	5	4	7
Chlorophyll a(µg/l)	Surface	1.1	1.0	1.3	1.9	0.8	0.5	1.9	1.8	4.8	2.7	2.0	3.6	2.1	0.7	0.2
Total coliform (MPN/100ml)	Surface	7500	1100	1500	1500	4300	2400	4200	400	3500	2000	2700	12000	1500	3400	21000
Fecal coliform (MPN/100ml)	Surface	700	700	300	200	400	600	1500	75	700	600	900	1500	300	1500	1100
NH4/NH3-N (mg/l)	Surface	<0.02	<0.02	<0.02	<0.02	0.02	0.02	0.02	<0.02	0.03	0.02	<0.02	<0.02	0.02	0.02	0.02
NO3-N (mg/l)	Surface	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.11	0.13	0.06
	Bottom															
PO4-P (mg/l)	Surface	0.02	0.01	0.01	0.04	0.02	0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.01	0.03
	Bottom															
TN (mg/l)	Surface	<0.05	<0.05	0.35	<0.05	0.08	0.17	0.31	0.16	0.10	0.51	<0.05	0.14	0.56	0.20	0.24
	Bottom															
TP (mg/l)	Surface	0.05	0.06	0.04	0.07	0.05	0.05	0.01	0.04	0.02	0.03	0.02	0.04	0.06	0.05	0.07
	Bottom															
Copper	Water (µg/l)	38.6			<0.01			61.4			81.4			134		
	Sediment (µg/kg)	90400			73180			92940			25600			21500		
Lead	Water (µg/l)	0.55			1.03			0.90			0.43			0.26		
	Sediment (µg/kg)	42940			29760			32160			24580			13160		

Parameter	Layer	Site/Station														
		A			**B**			**C**			**D**			**E**		
		1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***
Cadmium	Water (µg/l)	6.58			0.54			0.15			0.31			0.15		
	Sediment (µg/kg)	620			240			80			320			580		
Zinc	Water (µg/l)	0.38			8.33			9.89			8.26			0.13		
	Sediment (µg/kg)	33520			37900			34760			23800			34240		
p,p'-DDE	Water (µg/l)	< MDL														
	Sediment (µg/kg)	0.86			0.56			0.50			0.72			0.65		
p,p'-DDD	Water (µg/l)	< MDL														
	Sediment (µg/kg)	0.45			0.36			3.50			0.80			1.35		
p,p'-DDT	Water (µg/l)	< MDL														
	Sediment (µg/kg)	0.21			<0.15			0.65			0.30			1.70		
∑ DDTs	Water (µg/l)	< MDL														
	Sediment (µg/kg)	1.52			0.92			4.65			1.82			3.70		
α-HCH	Water (µg/l)	< MDL														
	Sediment (µg/kg)	0.34			0.35			0.25			0.30			0.25		
β-HCH	Water (µg/l)	< MDL														
	Sediment (µg/kg)	< 0.05			< 0.05			< 0.05			< 0.05			< 0.05		
δ-HCH	Water (µg/l)	< MDL														
	Sediment (µg/kg)	< 0.05			< 0.05			0.15			0.15			0.90		
∑ HCHs	Water (µg/l)	< MDL														
	Sediment (µg/kg)	0.34			0.35			0.40			0.45			1.15		

$\mu g.kg^{-1}$ dw (dry weight)

MDL: Method Detection Limit (Copper: 0.01 µg/l; Lead: 0.25 µg/l; Cadmium: 0.01 µg/l; Zinc: 0.25 µg/l: DDTs: 0.0005 µg/l; HCHs: 0.0002 µg/l)

Appendix A5. ANALYSIS RESULTS OF TAM GIANG LAGOON WATER AND SEDIMENT SAMPLES (IMOLA PROJECT)
May - 2007

Parameter	Layer	Site/Station														
		A			**B**			**C**			**D**			**E**		
		1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***
Temperature (^{o}C)																
pH																
Salinity ($^{0}/_{00}$)																
Transparency (cm)																
DO (mg/l)																
BOD5 (mg/l)	Surface	0.9	1.3	1.5	0.6	0.5	1.0	0.8	0.6	0.6	0.5	0.7	0.8	0.5	0.5	0.4
COD (mg/l)	Surface	4.5	3.6	7.2	1.6	3.2	2.8	5.6	5.2	3.4	7.6	5.4	7.0	5.1	4.4	4.6
Chlorophyll a(µg/l)	Surface	0.7	1.6	8.0	3.2	0.6	1.7	3.7	1.1	4.2	3.0	2.3	3.4	1.7	1.1	1.2
Total coliform (MPN/100ml)	Surface															
Fecal coliform (MPN/100ml)	Surface															
NH4/NH3-N (mg/l)	Surface	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02	<0.02	<0.02	0.02	0.05	0.04
NO3-N (mg/l)	Surface	<0.05	0.05	<0.05	<0.05	0.07	<0.05	0.11	<0.05	<0.05	0.06	0.12	0.10	0.06	0.20	0.09
	Bottom															
PO4-P (mg/l)	Surface	< 0.01	<0.01	0.02	0.02	0.04	<0.01	0.02	0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
	Bottom															
TN (mg/l)	Surface	0.28	0.29	<0.05	0.65	0.39	0.21	0.37	0.21	0.49	0.52	0.65	0.31	0.39	0.60	0.35
	Bottom															
TP (mg/l)	Surface	0.02	0.02	0.03	0.03	0.05	0.01	0.02	0.02	0.03	0.01	0.01	0.02	0.01	0.02	0.02
	Bottom															
Copper	Water (µg/l)	<0.01			<0.01			112			19.3			25.4		
	Sediment (µg/kg)	612000			393800			759600			714600			551800		
Lead	Water (µg/l)	0.89			1.19			<0.25			<0.25			0.6		
	Sediment (µg/kg)	25100			12300			14800			7000			11200		
Cadmium	Water (µg/l)	0.03			0.08			0.04			0.25			0.01		

Parameter	Layer	Site/Station														
		A			**B**			**C**			**D**			**E**		
		1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***
	Sediment (µg/kg)	400			1200			3000			1200			1300		
Zinc	Water (µg/l)	22.8			10.5			12.3			17.7			21.5		
	Sediment (µg/kg)	99900			53200			87900			70300			58300		
p,p'-DDE	Water (µg/l)															
	Sediment (µg/kg)	1.00			1.90			0.80			1.10			2.40		
p,p'-DDD	Water (µg/l)															
	Sediment (µg/kg)	1.70			0.70			1.10			1.60			2.80		
p,p'-DDT	Water (µg/l)															
	Sediment (µg/kg)	3.50			1.00			8.40			5.50			<0.15		
∑ DDTs	Water (µg/l)															
	Sediment (µg/kg)	6.20			3.60			10.3			8.20			5.20		
α-HCH	Water (µg/l)															
	Sediment (µg/kg)	0.40			3.80			1.10			0.20			1.00		
β-HCH	Water (µg/l)															
	Sediment (µg/kg)	1.70			<0.05			4.60			1.40			0.40		
δ-HCH	Water (µg/l)															
	Sediment (µg/kg)	<0.05			1.60			2.30			1.50			1.20		
∑ HCHs	Water (µg/l)															
	Sediment (µg/kg)	2.10			5.40			8.00			3.10			2.60		

µg.kg $^{-1}$ dw (dry weight)

MDL: Method Detection Limit (Copper: 0.01 µg/l; Lead: 0.25 µg/l; Cadmium: 0.01 µg/l; Zinc: 0.25 µg/l: DDTs: 0.0005 µg/l; HCHs: 0.0002 µg/l)

Appendix B1. ANALYSIS RESULTS OF THUY TU LAGOON WATER AND SEDIMENT SAMPLES (IMOLA PROJECT)

April - 2006

Parameter	Layer	Site/Station											
		F			**G**			**H**			**I**		
		16	***17***	***18***	***19***	***20***	***21***	***22***	***23***	***24***	***25***	***26***	***27***
Temperature (^oC)		26.4	27.1	27.9	29.7	29.3	29.2	29.5	29.7	30.2	30.6	31.2	31.0
pH		8.1	8.2	8.5	8.2	8.1	8.2	8.2	8.3	8.3	8.4	8.6	8.4
Salinity ($^0/_{00}$)		19.0	21.0	15.5	17.5	17.0	18.0	16.0	15.5	16.5	13.5	16.0	18.5
Transparency (cm)		100	180	90	130	190	30	140	250	250	120	270	260
DO (mg/l)		6.8	6.9	7.1	6.9	7.1	6.3	7.7	7.9	7.6	7.1	7.2	7.3
BOD5 (mg/l)	Surface	1.1	1.0	0.9	2.2	2.1	2.0	1.6	2.1	1.8	0.7	0.9	1.2
COD (mg/l)	Surface	7	7	9	7	6	7	5	5	5	6	5	6
Chlorophyll a(μg/l)	Surface	2.3	2.2	1.1	3.2	2.7	3.5	3.3	1.7	0.9	0.9	1.1	1.5
Total coliform (MPN/100ml)	Surface	0	11000	7500	5400	4500	0	7500	2100	11000	2300	0	3100
Fecal coliform (MPN/100ml)	Surface	0	2300	210	110	110	0	2100	0	2100	110	0	75
NH4/NH3-N (mg/l)	Surface	< 0.02	0.05	0.12	0.04	0.05	0.07	< 0.02	< 0.02	0.03	< 0.02	< 0.02	0.02
NO2-N (mg/l)	Surface	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
NO3-N (mg/l)	Surface	< 0.05	< 0.05	0.05	< 0.05	0.06	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
	Bottom		0.15			0.13			0.05	0.05		0.06	
PO4-P (mg/l)	Surface	0.03	0.03	0.03	0.01	< 0.01	0.03	0.03	0.04	0.03	0.03	0.05	0.02
	Bottom		0.03			< 0.01			< 0.01	0.01		< 0.01	
TN (mg/l)	Surface	1.07	0.72	0.65	1.89	2.88	1.27	1.16	1.60	0.85	1.65	0.78	0.69
	Bottom		0.79			0.32			0.36	0.79		0.82	
TP (mg/l)	Surface	0.05	0.05	0.07	0.03	0.04	0.06	0.06	0.07	0.06	0.07	0.09	0.05
	Bottom		0.05			< 0.01			< 0.01	0.02		< 0.01	
Copper	Water (μg/l)		0.50			2.98			0.88			1.14	
	Sediment (μg/kg)		1980			9640			6780			880	

Parameter	Layer	Site/Station											
		F			**G**			**H**			**I**		
		16	***17***	***18***	***19***	***20***	***21***	***22***	***23***	***24***	***25***	***26***	***27***
Lead	Water (µg/l)	0.85			1.20			1.30			0.95		
	Sediment (µg/kg)	17400			7060			8050			12500		
Cadmium	Water (µg/l)	0.05			0.08			0.08			0.22		
	Sediment (µg/kg)	260			165			550			690		
Zinc	Water (µg/l)	2.88			3.12			3.24			42.1		
	Sediment (µg/kg)	30720			66000			32220			36060		
p,p'-DDE	Water (µg/l)	< MDL											
	Sediment (µg/kg)	0.49			0.43			1.48			0.53		
p,p'-DDD	Water (µg/l)	< MDL											
	Sediment (µg/kg)	< 0.15			< 0.15			1.33			0.38		
p,p'-DDT	Water (µg/l)	< MDL											
	Sediment (µg/kg)	< 0.15			< 0.15			1.54			3.64		
∑ DDTs	Water (µg/l)	< MDL											
	Sediment (µg/kg)	0.49			0.43			4.35			4.55		
α-HCH	Water (µg/l)	< MDL											
	Sediment (µg/kg)	0.14			0.12			0.24			0.16		
β-HCH	Water (µg/l)	< MDL											
	Sediment (µg/kg)	< 0.05			< 0.05			< 0.05			< 0.05		
δ-HCH	Water (µg/l)	1.30											
	Sediment (µg/kg)	0.07			1.94			1.28			2.10		
∑ HCHs	Water (µg/l)	< MDL											
	Sediment (µg/kg)	0.21			2.06			1.52			2.26		

µg.kg $^{-1}$ dw (dry weight)

MDL: Method Detection Limit (Copper: 0.01 µg/l; Lead: 0.25 µg/l; Cadmium: 0.01 µg/l; Zinc: 0.25 µg/l: DDTs: 0.0005 µg/l; HCHs: 0.0002 µg/l)

Appendix B2. ANALYSIS RESULTS OF THUY TU LAGOON WATER AND SEDIMENT SAMPLES (IMOLA PROJECT)

May - 2006

Parameter	Layer	Site/Station											
		F			G			H			I		
		16	***17***	***18***	***19***	***20***	***21***	***22***	***23***	***24***	***25***	***26***	***27***
Temperature (^oC)		30.0	30.1	30.5	31.8	31.6	32.3	32.0	31.1	32.1	31.0	31.0	31.4
pH		8.0	8.1	8.0	8.3	8.1	8.2	8.4	8.2	8.2	8.2	8.2	8.2
Salinity ($^0/_{00}$)		23.0	24.0	21.0	25.0	24.0	25.0	23.0	22.5	22.5	21.5	20.0	19.0
Transparency (cm)		90	100	100	140	110	60	90	100	100	120	150	130
DO (mg/l)		6.2	6.8	6.0	7.9	6.9	7.8	7.8	7.4	7.6	7.6	7.1	7.2
BOD5 (mg/l)	Surface	2.2	1.3	2.0	2.0	1.5	2.3	1.6	1.8	1.8	2.0	1.7	1.8
COD (mg/l)	Surface	6	3	4	5	7	6	5	5	3	5	4	4
Chlorophyll a(μg/l)	Surface	3.2	1.6	1.5	3.2	4.3	2.8	6.1	1.7	4.5	4.7	6.7	2.9
Total coliform (MPN/100ml)	Surface	2100	110000	2300	4300	24000	4300	15000	>240000	2800	4300	7500	24000
Fecal coliform (MPN/100ml)	Surface	700	2800	400	700	700	1500	1500	1500	700	1500	700	2100
NH4/NH3-N (mg/l)	Surface	0.05	0.05	0.04	0.05	0.04	0.05	0.08	0.04	0.04	0.04	0.05	0.05
NO2-N (mg/l)	Surface	0.004	0.003	0.002	0.002	0.004	0.002	0.004	0.004	0.004	0.003	0.004	0.004
NO3-N (mg/l)	Surface	0.08	0.06	0.07	0.08	0.07	0.05	0.10	0.08	0.06	0.06	0.07	0.06
	Bottom		0.09			0.06					0.05	0.05	0.05
PO4-P (mg/l)	Surface	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Bottom		<0.01			<0.01					<0.01	<0.01	<0.01
TN (mg/l)	Surface	0.54	0.90	1.72	1.47	1.32	1.63	0.95	0.94	1.02	1.81	1.34	1.22
	Bottom		0.69			2.09					0.98	2.68	0.76
TP (mg/l)	Surface	0.05	0.02	0.03	0.04	0.04	0.03	0.04	0.04	0.04	0.06	0.04	0.04
	Bottom		0.04			0.07					0.04	0.09	0.09
Copper	Water (μg/l)	0.10			0.86			0.56			1.30		
	Sediment (μg/kg)	6040			2220			4600			3120		
Lead	Water (μg/l)	0.87			0.90			0.82			0.75		
	Sediment (μg/kg)	13600			12500			26600			4240		

<table>
<tr><th rowspan="3">Parameter</th><th rowspan="3">Layer</th><th colspan="12">Site/Station</th></tr>
<tr><th colspan="3">F</th><th colspan="3">G</th><th colspan="3">H</th><th colspan="3">I</th></tr>
<tr><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th><th>21</th><th>22</th><th>23</th><th>24</th><th>25</th><th>26</th><th>27</th></tr>
<tr><td rowspan="2">Cadmium</td><td>Water (μg/l)</td><td colspan="3">0.05</td><td colspan="3">0.08</td><td colspan="3">0.08</td><td colspan="3">0.05</td></tr>
<tr><td>Sediment (μg/kg)</td><td colspan="3">340</td><td colspan="3">240</td><td colspan="3">340</td><td colspan="3">280</td></tr>
<tr><td rowspan="2">Zinc</td><td>Water (μg/l)</td><td colspan="3">2.88</td><td colspan="3">14.9</td><td colspan="3">3.84</td><td colspan="3">3.30</td></tr>
<tr><td>Sediment (μg/kg)</td><td colspan="3">7560</td><td colspan="3">33840</td><td colspan="3">32760</td><td colspan="3">36660</td></tr>
<tr><td rowspan="2">p,p’-DDE</td><td>Water (μg/l)</td><td colspan="12">< MDL</td></tr>
<tr><td>Sediment (μg/kg)</td><td colspan="3">0.77</td><td colspan="3">0.67</td><td colspan="3">0.67</td><td colspan="3">0.54</td></tr>
<tr><td rowspan="2">p,p’-DDD</td><td>Water (μg/l)</td><td colspan="12">< MDL</td></tr>
<tr><td>Sediment (μg/kg)</td><td colspan="3">2.01</td><td colspan="3">0.86</td><td colspan="3">1.49</td><td colspan="3">0.77</td></tr>
<tr><td rowspan="2">p,p’-DDT</td><td>Water (μg/l)</td><td colspan="12">< MDL</td></tr>
<tr><td>Sediment (μg/kg)</td><td colspan="3">< 0.15</td><td colspan="3">< 0.15</td><td colspan="3">< 0.15</td><td colspan="3">0.68</td></tr>
<tr><td rowspan="2">∑ DDTs</td><td>Water (μg/l)</td><td colspan="12">< MDL</td></tr>
<tr><td>Sediment (μg/kg)</td><td colspan="3">2.78</td><td colspan="3">1.53</td><td colspan="3">2.16</td><td colspan="3">1.99</td></tr>
<tr><td rowspan="2">α-HCH</td><td>Water (μg/l)</td><td colspan="12">4.42</td></tr>
<tr><td>Sediment (μg/kg)</td><td colspan="3">0.15</td><td colspan="3">0.17</td><td colspan="3">0.13</td><td colspan="3">0.18</td></tr>
<tr><td rowspan="2">β-HCH</td><td>Water (μg/l)</td><td colspan="12">< MDL</td></tr>
<tr><td>Sediment (μg/kg)</td><td colspan="3">< 0.05</td><td colspan="3">< 0.05</td><td colspan="3">< 0.05</td><td colspan="3">< 0.05</td></tr>
<tr><td rowspan="2">δ-HCH</td><td>Water (μg/l)</td><td colspan="12">< MDL</td></tr>
<tr><td>Sediment (μg/kg)</td><td colspan="3">1.65</td><td colspan="3">0.37</td><td colspan="3">1.37</td><td colspan="3">0.75</td></tr>
<tr><td rowspan="2">∑ HCHs</td><td>Water (μg/l)</td><td colspan="12">4.42</td></tr>
<tr><td>Sediment (μg/kg)</td><td colspan="3">1.80</td><td colspan="3">0.54</td><td colspan="3">1.50</td><td colspan="3">0.93</td></tr>
</table>

$\mu g.kg^{-1}$ dw (dry weight)

MDL: Method Detection Limit (Copper: 0.01 μg/l; Lead: 0.25 μg/l; Cadmium: 0.01 μg/l; Zinc: 0.25 μg/l: DDTs: 0.0005 μg/l; HCHs: 0.0002 μg/l)

Appendix B3. ANALYSIS RESULTS OF THUY TU LAGOON WATER AND SEDIMENT SAMPLES (IMOLA PROJECT)

August - 2006

Parameter	Layer	Site/Station											
		F			G			H			I		
		16	***17***	***18***	***19***	***20***	***21***	***22***	***23***	***24***	***25***	***26***	***27***
Temperature (^{o}C)		32.5	31.8	31.6	30.8	30.5	30.5	31.4	31.6	31.3	32.0	32.0	31.5
pH		7.6	8.2	8.2	8.0	7.9	7.7	8.1	8.1	8.1	8.0	7.9	7.7
Salinity ($^{0}/_{00}$)		4.5	12.5	13.0	22.0	23.0	21.5	17.0	19.0	18.0	13.5	13.5	11.0
Transparency (cm)		100	100	140							150	170	150
DO (mg/l)		6.3	7.1	6.5	6.6	6.7	7.1	7.1	7.1	6.9	7.0	7.2	7.1
BOD5 (mg/l)	Surface	3.6	2.0	4.7	3.8	3.7	3.8	3.6	3.8	3.5	2.5	2.5	2.3
COD (mg/l)	Surface	9	9	14	9	10	7	9	6	6	6	6	4
Chlorophyll a(µg/l)	Surface	14.9	12.4	24.8	7.0	6.4	6.9	6.4	7.2	7.1	7.6	6.5	12.0
Total coliform (MPN/100ml)	Surface	110000	2800	700	2000	1100	2700	15000	15000	2000	400	200	400
Fecal coliform (MPN/100ml)	Surface	700	700	400	700	400	700	700	1500	400	200	200	400
NH4/NH3-N (mg/l)	Surface	0.05	0.03	0.03	0.03	0.02	0.03	0.04	0.03	0.02	0.05	0.04	0.02
NO3-N (mg/l)	Surface	0.13	0.10	0.07	0.05	0.06	<0.05	<0.05	0.05	0.06	<0.05	0.06	<0.05
	Bottom					<0.05			0.05		<0.05	<0.05	<0.05
PO4-P (mg/l)	Surface	0.02	0.05	0.01	0.02	0.01	<0.01	0.02	0.02	0.02	0.01	<0.01	0.01
	Bottom					0.02			0.02		0.03	<0.01	0.02
TN (mg/l)	Surface	0.33	0.43	0.42	0.47	0.29	0.69	0.53	0.42	0.53	0.48	0.36	0.77
	Bottom					0.46			0.13		0.30	0.27	0.22
TP (mg/l)	Surface	0.04	0.08	0.02	0.04	0.03	0.04	0.06	0.05	0.05	0.04	0.02	0.04
	Bottom					0.05			0.08		0.07	0.04	0.05
Copper	Water (µg/l)	3.38			6.14			3.36			2.56		
	Sediment (µg/kg)	5908			5573			10018			12196		
Lead	Water (µg/l)	0.56			1.28			1.45			0.48		
	Sediment (µg/kg)	19707			22557			43081			41324		

<table>
<tr><th rowspan="3">Parameter</th><th rowspan="3">Layer</th><th colspan="12">Site/Station</th></tr>
<tr><th colspan="3">F</th><th colspan="3">G</th><th colspan="3">H</th><th colspan="3">I</th></tr>
<tr><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th><th>21</th><th>22</th><th>23</th><th>24</th><th>25</th><th>26</th><th>27</th></tr>
<tr><td rowspan="2">Cadmium</td><td>Water (µg/l)</td><td colspan="3">0.46</td><td colspan="3">0.76</td><td colspan="3">0.29</td><td colspan="3">0.24</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">144</td><td colspan="3">178</td><td colspan="3">611</td><td colspan="3">378</td></tr>
<tr><td rowspan="2">Zinc</td><td>Water (µg/l)</td><td colspan="3">2.45</td><td colspan="3">4.65</td><td colspan="3">3.53</td><td colspan="3">0.65</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">83700</td><td colspan="3">44100</td><td colspan="3">19800</td><td colspan="3">108900</td></tr>
<tr><td rowspan="2">p,p’-DDE</td><td>Water (µg/l)</td><td colspan="12">< MDL</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">0.97</td><td colspan="3">0.85</td><td colspan="3">0.85</td><td colspan="3">0.50</td></tr>
<tr><td rowspan="2">p,p’-DDD</td><td>Water (µg/l)</td><td colspan="12">< MDL</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">2.35</td><td colspan="3">1.06</td><td colspan="3">1.75</td><td colspan="3">0.70</td></tr>
<tr><td rowspan="2">p,p’-DDT</td><td>Water (µg/l)</td><td colspan="12">< MDL</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">< 0.15</td><td colspan="3">< 0.15</td><td colspan="3">< 0.15</td><td colspan="3">0.70</td></tr>
<tr><td rowspan="2">∑ DDTs</td><td>Water (µg/l)</td><td colspan="12">< MDL</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">3.34</td><td colspan="3">1.91</td><td colspan="3">1.60</td><td colspan="3">1.90</td></tr>
<tr><td rowspan="2">α-HCH</td><td>Water (µg/l)</td><td colspan="12">3.35</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">0.20</td><td colspan="3">0.20</td><td colspan="3">0.15</td><td colspan="3">0.28</td></tr>
<tr><td rowspan="2">β-HCH</td><td>Water (µg/l)</td><td colspan="12">< MDL</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">< 0.05</td><td colspan="3">< 0.05</td><td colspan="3">< 0.05</td><td colspan="3">< 0.05</td></tr>
<tr><td rowspan="2">δ-HCH</td><td>Water (µg/l)</td><td colspan="12">2.30</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">2.0</td><td colspan="3">0.50</td><td colspan="3">1.50</td><td colspan="3">0.82</td></tr>
<tr><td rowspan="2">∑ HCHs</td><td>Water (µg/l)</td><td colspan="12">5.65</td></tr>
<tr><td>Sediment (µg/kg)</td><td colspan="3">2.20</td><td colspan="3">0.70</td><td colspan="3">1.55</td><td colspan="3">1.10</td></tr>
</table>

$\mu g.kg^{-1}$ dw (dry weight)

MDL: Method Detection Limit (Copper: 0.01 µg/l; Lead: 0.25 µg/l; Cadmium: 0.01 µg/l; Zinc: 0.25 µg/l: DDTs: 0.0005 µg/l; HCHs: 0.0002 µg/l)

Appendix B4. ANALYSIS RESULTS OF THUY TU LAGOON WATER AND SEDIMENT SAMPLES (IMOLA PROJECT)

November - 2006

Parameter	Layer	Site/Station											
		F			**G**			**H**			**I**		
		16	***17***	***18***	***19***	***20***	***21***	***22***	***23***	***24***	***25***	***26***	***27***
Temperature (^oC)		28.8	29.0	29.3	27.5	28.1	27.3	28.0	28.6	28.1	30.3	31.9	32.3
pH		8.2	8.2	8.2	7.8	8.1	8.0	7.9	8.0	8.0	8.2	8.0	8.1
Salinity ($^0/_{00}$)		10.0	18.0	7.0	13.5	18.0	11.5	9.3	9.3	9.3	13.0	17.3	18.3
Transparency (cm)		160	150	100	190	220	160	140	230	160	150	200	230
DO (mg/l)		6.4	6.5	5.5	6.2	6.0	5.9	6.1	6.2	6.4	6.5	6.2	6.6
BOD5 (mg/l)	Surface	0.6	0.4	0.4	0.5	0.4	0.5	0.4	0.3	0.3	0.5	0.7	0.6
COD (mg/l)	Surface	9	6	7	5	5	4	5	5	5	4	5	5
Chlorophyll a(µg/l)	Surface	1.6	2.5	1.5	1.8	2.5	0.4	2.4	3.0	3.3	1.0	1.2	0.5
Total coliform (MPN/100ml)	Surface	4400	2000	700	300	2300	900	1200	4300	15000	2700	1500	1400
Fecal coliform (MPN/100ml)	Surface	1500	600	110	75	400	300	600	900	400	1100	700	400
NH4/NH3-N (mg/l)	Surface	<0.02	<0.02	0.02	0.06	<0.02	0.02	0.02	<0.02	<0.02	0.02	0.02	<0.02
NO3-N (mg/l)	Surface	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Bottom												
PO4-P (mg/l)	Surface	0.02	0.04	0.03	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
	Bottom												
TN (mg/l)	Surface	0.27	0.06	1.56	1.82	2.56	1.79	1.57	2.22	2.24	1.54	1.48	1.61
	Bottom												
TP (mg/l)	Surface	0.06	0.08	0.06	0.04	0.02	0.02	0.03	0.03	<0.01	0.02	0.04	0.01
	Bottom												
Copper	Water (µg/l)	47.8			17.3			119			140		
	Sediment (µg/kg)	23420			19860			29580			23 860		
Lead	Water (µg/l)	1.15			0.01			1.06			3.68		
	Sediment (µg/kg)	25920			18700			13820			30320		

Parameter	Layer	Site/Station											
			F			**G**			**H**			**I**	
		16	***17***	***18***	***19***	***20***	***21***	***22***	***23***	***24***	***25***	***26***	***27***
Cadmium	Water (μg/l)		1.04			0.40			1.28			4.89	
	Sediment (μg/kg)		580			120			50			630	
Zinc	Water (μg/l)		5.74			5.03			7.76			4.46	
	Sediment (μg/kg)		26080			26660			27620			34520	
p,p'-DDE	Water (μg/l)	<MDL											
	Sediment (μg/kg)		0.77			0.90			1.05			0.65	
p,p'-DDD	Water (μg/l)	<MDL											
	Sediment (μg/kg)		1.55			< 0.15			1.25			0.80	
p,p'-DDT	Water (μg/l)	<MDL											
	Sediment (μg/kg)		< 0.15			< 0.15			0.35			0.85	
∑ DDTs	Water (μg/l)	<MDL											
	Sediment (μg/kg)		2.32			0.90			2.65			2.30	
α-HCH	Water (μg/l)	<MDL											
	Sediment (μg/kg)		0.15			0.15			0.20			0.20	
β-HCH	Water (μg/l)	<MDL											
	Sediment (μg/kg)		< 0.05			< 0.05			< 0.05			<0.05	
δ-HCH	Water (μg/l)	<MDL											
	Sediment (μg/kg)		1.50			0.60			0.95			0.75	
∑ HCHs	Water (μg/l)	<MDL											
	Sediment (μg/kg)		1.65			0.75			1.15			0.95	

$\mu g.kg^{-1}$ dw (dry weight)

MDL: Method Detection Limit (Copper: 0.01 μg/l; Lead: 0.25 μg/l; Cadmium: 0.01 μg/l; Zinc: 0.25 μg/l: DDTs: 0.0005 μg/l; HCHs: 0.0002 μg/l)

Appendix B5. ANALYSIS RESULTS OF THUY TU LAGOON WATER AND SEDIMENT SAMPLES (IMOLA PROJECT)

May - 2007

Parameter	Layer	Site/Station											
		F			**G**			**H**			**I**		
		16	***17***	***18***	***19***	***20***	***21***	***22***	***23***	***24***	***25***	***26***	***27***
Temperature (°C)													
pH													
Salinity (‰)													
Transparency (cm)													
DO (mg/l)													
BOD5 (mg/l)	Surface	1.0	1.1	1.7	1.2	1.0	1.1	1.3	1.5	1.5	1.6	1.4	1
COD (mg/l)	Surface	8.8	9.6	9.8	4.5	2.3	2.0	6.7	6.3	5.2	2.6	3.2	1.7
Chlorophyll a(μg/l)	Surface	3.8	2.7	3.6	2.5			2.8				4.0	
Total coliform (MPN/100ml)	Surface												
Fecal coliform (MPN/100ml)	Surface												
NH4/NH3-N (mg/l)	Surface	0.02	0.02	<0.02	0.02	0.04	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
NO3-N (mg/l)	Surface	0.06	0.06	0.06	<0.05	0.06	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Bottom												
PO4-P (mg/l)	Surface	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
	Bottom												
TN (mg/l)	Surface	0.78	1.05	1.28	1.53	0.62	0.93	0.91	1.08	0.67	0.78	1.30	0.96
	Bottom												
TP (mg/l)	Surface	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.03	0.02	0.02
	Bottom												
Copper	Water (μg/l)	4.35			36.0			<0.01			<0.01		
	Sediment (μg/kg)	10798						623600			1087600		
Lead	Water (μg/l)	0.30			0.31			0.28			0.55		
	Sediment (μg/kg)	13200			7900			32200			44600		

Parameter	Layer	Site/Station											
		F			**G**			**H**			**I**		
		16	***17***	***18***	***19***	***20***	***21***	***22***	***23***	***24***	***25***	***26***	***27***
Cadmium	Water (µg/l)	0.03			0.06			0.01			0.10		
	Sediment (µg/kg)	900			1100			1200			300		
Zinc	Water (µg/l)	4.10			6.74			8.05			18.0		
	Sediment (µg/kg)	63800			68600			109300			137300		
p,p'-DDE	Water (µg/l)												
	Sediment (µg/kg)	<0.15			2.00			1.90			<0.15		
p,p'-DDD	Water (µg/l)												
	Sediment (µg/kg)	1.20			1.00			0.30			2.50		
p,p'-DDT	Water (µg/l)												
	Sediment (µg/kg)	1.40			<0.15			0.10			0.80		
∑ DDTs	Water (µg/l)												
	Sediment (µg/kg)	2.60			3.00			2.30			3.30		
α-HCH	Water (µg/l)												
	Sediment (µg/kg)	1.80			<0.05			0.10			0.60		
β-HCH	Water (µg/l)												
	Sediment (µg/kg)	1.00			2.00			1.30			<0.05		
δ-HCH	Water (µg/l)												
	Sediment (µg/kg)	1.30			1.50			3.70			1.80		
∑ HCHs	Water (µg/l)												
	Sediment (µg/kg)	4.10			3.50			5.10			2.40		

$\mu g.kg^{-1}$ dw (dry weight)

MDL: Method Detection Limit (Copper: 0.01 µg/l; Lead: 0.25 µg/l; Cadmium: 0.01 µg/l; Zinc: 0.25 µg/l: DDTs: 0.0005 µg/l; HCHs: 0.0002 µg/l)

Appendix C1. ANALYSIS RESULTS OF CAU HAI LAGOON WATER AND SEDIMENT SAMPLES (IMOLA PROJECT)

April - 2006

Parameter	Layer	Site/Station									
		J			**K**			**L**			
		30	***29***	***28***	***31***	***32***	***33***	***34***	***35***	***36***	***37***
Temperature (^oC)		24.8	29.2	31.3	29.8	31.0	30.5	29.5	31.0	31.4	30.3
pH		8.1	8.4	8.3	8.8	8.1	8.1	8.3	8.5	8.8	8.4
Salinity ($^0/_{00}$)		29.5	15.0	12.0	10.0	14.0	15.0	20.0	11.0	11.0	7.0
Transparency (cm)		250	100	80	120	180	130	210	190	130	160
DO (mg/l)		6.3	6.3	6.4	6.9	6.9	6.8	6.9	7.0	7.2	6.1
BOD5 (mg/l)	Surface	0.6	0.8	0.8	1.1	0.7	1.5	1.2	1.1	0.9	1.1
COD (mg/l)	Surface	6	6	7	5	6	9	7	5	8	7
Chlorophyll a(µg/l)	Surface	0.9	1.3	1.1	2.4	0.9	2.6	3.1	2.4	1.3	2.2
Total coliform (MPN/100ml)	Surface	3100	7500	150	11000	11000	2400	4500	2400	1100	2500
Fecal coliform (MPN/100ml)	Surface	75	1100	50	0	460	150	110	150	0	150
NH4/NH3-N (mg/l)	Surface	0.08	0.06	0.12	0.05	0.08	0.10	0.13	0.08	0.14	0.11
NO2-N (mg/l)	Surface	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
NO3-N (mg/l)	Surface	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.05	< 0.05	< 0.05	< 0.05	0.05
	Bottom			< 0.05		< 0.05		< 0.05		0.05	< 0.05
PO4-P (mg/l)	Surface	0.02	0.03	0.02	0.01	0.03	0.01	0.01	0.01	< 0.01	0.01
	Bottom			< 0.01		0.02		< 0.01		< 0.01	< 0.01
TN (mg/l)	Surface	1.48	0.75	0.71	0.85	0.97	1.18	0.88	0.64	0.58	0.79
	Bottom			0.84		0.90		0.82		0.80	0.14
TP (mg/l)	Surface	0.06	0.05	0.05	0.03	0.06	0.03	0.03	0.04	0.02	0.03
	Bottom			< 0.01		0.05		< 0.01		< 0.01	< 0.01
Copper	Water (µg/l)	0.80			0.70				1.06		
	Sediment (µg/kg)	2100			4720				4020		
Lead	Water (µg/l)	1.20			0.85				0.90		
	Sediment (µg/kg)	12300			55400				37000		

Parameter	Layer	Site/Station									
		J			**K**			**L**			
		30	***29***	***28***	***31***	***32***	***33***	***34***	***35***	***36***	***37***
Cadmium	Water (μg/l)	0.04			0.05				0.05		
	Sediment (μg/kg)	740			1130				210		
Zinc	Water (μg/l)	3.84			15.8				4.86		
	Sediment (μg/kg)	79800			34860				31440		
p,p’-DDE	Water (μg/l)	< MDL									
	Sediment (μg/kg)	< 0.15			0.24				0.50		
p,p’-DDD	Water (μg/l)	< MDL									
	Sediment (μg/kg)	< 0.15			< 0.15				< 0.15		
p,p’-DDT	Water (μg/l)	< MDL									
	Sediment (μg/kg)	< 0.15			< 0.15				< 0.15		
∑ DDTs	Water (μg/l)	< MDL									
	Sediment (μg/kg)	< 0.05			0.24				0.50		
α-HCH	Water (μg/l)	3.07									
	Sediment (μg/kg)	< 0.05			0.05				0.21		
β-HCH	Water (μg/l)	< MDL									
	Sediment (μg/kg)	0.83			< 0.05				< 0.05		
δ-HCH	Water (μg/l)	11.8									
	Sediment (μg/kg)	0.33			< 0.05				1.15		
∑ HCHs	Water (μg/l)	14.9									
	Sediment (μg/kg)	1.16			0.05				1.36		

$\mu g.kg^{-1}$ dw (dry weight)

MDL: Method Detection Limit (Copper: 0.01 μg/l; Lead: 0.25 μg/l; Cadmium: 0.01 μg/l; Zinc: 0.25 μg/l: DDTs: 0.0005 μg/l; HCHs: 0.0002 μg/l)

Appendix C2. ANALYSIS RESULTS OF CAU HAI LAGOON WATER AND SEDIMENT SAMPLES (IMOLA PROJECT)

May - 2006

Parameter	Layer	Site/Station									
		J			**K**			**L**			
		28	***29***	***30***	***31***	***32***	***33***	***34***	***35***	***36***	***37***
Temperature (^{o}C)		31.7	31.5	28.0	31.2	32.6	32.4	31.5	33.2	33.3	32.0
pH		8.5	8.5	8.0	8.3	8.4	8.1	8.4	8.6	8.6	8.2
Salinity ($^{0}/_{00}$)		17.5	22.0	34.0	17.0	20.5	24.5	20.0	20.0	20.5	16.0
Transparency (cm)		80	100	200	110	140	110	150	150	130	140
DO (mg/l)		7.5	8.1	8.4	5.6	7.2	6.7	5.8	8.6	9.1	6.6
BOD5 (mg/l)	Surface	1.2	1.0	1.7	1.0	1.1	1.5	0.8	1.6	0.9	1.2
COD (mg/l)	Surface	5	9	10	9	7	7	8	8	4	4
Chlorophyll a (μg/l)	Surface	0.3	4.9	3.8	3.1	1.7	1.5	1.2	0.7	1.3	2.5
Total coliform (MPN/100ml)	Surface	24000	2100	15000	3500	7500	110000	3500	15000	110000	110000
Fecal coliform (MPN/100ml)	Surface	1100	1500	700	700	1100	2800	700	1500	2800	2000
NH4/NH3-N (mg/l)	Surface	<0.02	0.06	0.04	<0.02	0.02	0.02	0.02	0.04	0.05	0.02
NO2-N (mg/l)	Surface	<0.002	<0.002	<0.002	0.002	<0.002	0.002	<0.002	<0.002	<0.002	<0.002
NO3-N (mg/l)	Surface	0.07	0.07	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07
	Bottom	0.05									<0.05
PO4-P (mg/l)	Surface	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Bottom	<0.01									<0.01
TN (mg/l)	Surface	2.10	1.08	1.81	3.46	0.83	0.81	1.06	0.55	0.76	0.81
	Bottom	3.35									1.31
TP (mg/l)	Surface	0.05	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.05	0.02
	Bottom	0.03									0.07
Copper	Water (μg/l)	0.82			1.00				0.76		
	Sediment (μg/kg)	440			6260				19980		

Parameter	Layer	Site/Station									
		J			**K**			**L**			
		28	***29***	***30***	***31***	***32***	***33***	***34***	***35***	***36***	***37***
Lead	Water (µg/l)	0.84			1.30				0.92		
	Sediment (µg/kg)	20700			36100				24800		
Cadmium	Water (µg/l)	0.09			0.04				0.05		
	Sediment (µg/kg)	4810			260				320		
Zinc	Water (µg/l)	3.48			4.32				4.08		
	Sediment (µg/kg)	32820			39060				42720		
p,p'-DDE	Water (µg/l)	< MDL									
	Sediment (µg/kg)	0.41			0.24				0.47		
p,p'-DDD	Water (µg/l)	< MDL									
	Sediment (µg/kg)	0.54			0.46				0.78		
p,p'-DDT	Water (µg/l)	< MDL									
	Sediment (µg/kg)	0.65			< 0.15				< 0.15		
∑ DDTs	Water (µg/l)	< MDL									
	Sediment (µg/kg)	1.60			0.70				1.25		
α-HCH	Water (µg/l)	0.86									
	Sediment (µg/kg)	0.12			0.12				0.22		
β-HCH	Water (µg/l)	< MDL									
	Sediment (µg/kg)	< 0.05			< 0.05				< 0.05		
δ-HCH	Water (µg/l)	< MDL									
	Sediment (µg/kg)	0.35			0.73				0.76		
∑ HCHs	Water (µg/l)	0.86									
	Sediment (µg/kg)	0.47			0.85				0.98		

$\mu g.kg^{-1}$ dw (dry weight)

MDL: Method Detection Limit (Copper: 0.01 µg/l; Lead: 0.25 µg/l; Cadmium: 0.01 µg/l; Zinc: 0.25 µg/l: DDTs: 0.0005 µg/l; HCHs: 0.0002 µg/l)

Appendix C3. ANALYSIS RESULTS OF CAU HAI LAGOON WATER AND SEDIMENT SAMPLES (IMOLA PROJECT)

August - 2006

Parameter	Layer	Site/Station									
		J			**K**			**L**			
		28	***29***	***30***	***31***	***32***	***33***	***34***	***35***	***36***	***37***
Temperature (^{o}C)		32.9	33.0	32.9	30.0	29.4	28.9	31.1	30.9	28.1	32.8
pH		7.7	7.0	7.5	7.6	7.8	7.9	7.1	7.5	7.8	7.7
Salinity ($^{0}/_{00}$)		1.0	<1	<1	16.0	15.0	24.0	25.0	25.0	26.0	3.0
Transparency (cm)			110	130	170	>100	>110	70	180	50	
DO (mg/l)		7.4	7.4	7.3	7.5	6.3	5.9	6.3	7.3	7.4	7.3
BOD5 (mg/l)	Surface	2.1	2.2	1.7	1.4	1.5	1.2	1.0	0.9	1.3	2.3
COD (mg/l)	Surface	4	7	6	6	5	4	6	8	8	5
Chlorophyll a(μg/l)	Surface	6.1	8.2	5.2	2.6	5.4	3.6	2.7	1.0	3.1	3.5
Total coliform (MPN/100ml)	Surface	15000	2000	750000	1500	2000	430000	150000	3500	2000	2800
Fecal coliform (MPN/100ml)	Surface	400	400	40000	400	700	40000	20000	1100	700	1100
NH4/NH3-N (mg/l)	Surface	0.10	0.06	0.08	0.03	0.03	0.03	0.03	0.05	0.04	0.08
NO3-N (mg/l)	Surface	<0.05	0.05	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Bottom							<0.05			
PO4-P (mg/l)	Surface	<0.01	0.01	0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Bottom							0.01			
TN (mg/l)	Surface	0.25	0.26	0.26	0.42	0.31	0.49	0.48	0.59	0.55	0.29
	Bottom							0.34			
TP (mg/l)	Surface	0.04	0.06	0.06	0.04	0.05	0.03	0.03	0.02	0.04	0.06
	Bottom							0.04			
Copper	Water (μg/l)	1.98			5.88				6.98		
	Sediment (μg/kg)	10568			6381				15643		
Lead	Water (μg/l)	1.83			1.15				0.79		
	Sediment (μg/kg)	14998			17066				22182		

Parameter	Layer	Site/Station									
		J			**K**			**L**			
		28	***29***	***30***	***31***	***32***	***33***	***34***	***35***	***36***	***37***
Cadmium	Water (µg/l)	1.01			9.29				2.30		
	Sediment (µg/kg)	881			300				367		
Zinc	Water (µg/l)	0.67			1.13				0.53		
	Sediment (µg/kg)	65700			53100				42300		
p,p'-DDE	Water (µg/l)	< MDL									
	Sediment (µg/kg)	0.62			0.35				0.77		
p,p'-DDD	Water (µg/l)	< MDL									
	Sediment (µg/kg)	0.84			0.76				1.05		
p,p'-DDT	Water (µg/l)	< MDL									
	Sediment (µg/kg)	0.72			0.25				0.45		
∑ DDTs	Water (µg/l)	< MDL									
	Sediment (µg/kg)	2.18			1.36				2.27		
α-HCH	Water (µg/l)	1.16									
	Sediment (µg/kg)	0.25			0.32				0.48		
β-HCH	Water (µg/l)	< MDL									
	Sediment (µg/kg)	< 0.05			< 0.05				< 0.05		
δ-HCH	Water (µg/l)	3.8									
	Sediment (µg/kg)	0.30			0.95				1.12		
∑ HCHs	Water (µg/l)	4.96									
	Sediment (µg/kg)	0.55			1.27				1.60		

$\mu g.kg^{-1}$ dw (dry weight)

MDL: Method Detection Limit (Copper: 0.01 µg/l; Lead: 0.25 µg/l; Cadmium: 0.01 µg/l; Zinc: 0.25 µg/l: DDTs: 0.0005 µg/l; HCHs: 0.0002 µg/l)

Appendix C4. ANALYSIS RESULTS OF CAU HAI LAGOON WATER AND SEDIMENT SAMPLES (IMOLA PROJECT)

November - 2006

Parameter	Layer	Site/Station									
		J			K			L			
		28	***29***	***30***	***31***	***32***	***33***	***34***	***35***	***36***	***37***
Temperature (^oC)		30.6	29.7	28.5	33.4	29.7	29.4	34.0	29.4	33.2	
pH		8.3	8.2	8.2	8.1	8.1	8.2	8.2	8.1	7.6	
Salinity ($^0/_{00}$)		15.0	19.3	33.5	16.0	10.0	17.5	17.0	17.0	19.5	
Transparency (cm)		150	155	150	250	200	150	230	160	150	
DO (mg/l)		6.1	5.9	5.9	5.9	6.2	6.1	6.4	6.1	6.0	
BOD5 (mg/l)	Surface	0.4	0.7	0.6	0.5	0.4	0.4	0.3	0.4	0.3	
COD (mg/l)	Surface	5	5	5	4	5	5	4	6	5	
Chlorophyll a(μg/l)	Surface	1.7	0.9	1.1	2.2	0.7	1.1	0.9	1.5	1.8	
Total coliform (MPN/100ml)	Surface	900	700	3900	7500	2600	1500	12000	2700	1100	
Fecal coliform (MPN/100ml)	Surface	400	110	2300	900	1100	600	3900	1100	300	
NH4/NH3-N (mg/l)	Surface	<0.02	<0.02	<0.02	<0.02	0.02	0.02	0.02	0.02	<0.02	
NO3-N (mg/l)	Surface	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
	Bottom										
PO4-P (mg/l)	Surface	<0.01	<0.01	<0.01	0.01	<0.01	0.01	0.02	<0.01	0.01	
	Bottom										
TN (mg/l)	Surface	1.57	1.57	1.39	0.90	1.25	1.92	0.74	1.10	0.79	
	Bottom										
TP (mg/l)	Surface	0.02	0.04	0.01	0.04	0.03	0.05	0.06	0.04	0.04	
	Bottom										
Copper	Water (μg/l)	26.7			108				102		
	Sediment (μg/kg)	49000			110760				94800		
Lead	Water (μg/l)	2.61			1.00				4.61		
	Sediment (μg/kg)	11820			32300				35960		

Parameter	Layer	Site/Station									
		J			**K**			**L**			
		28	***29***	***30***	***31***	***32***	***33***	***34***	***35***	***36***	***37***
Cadmium	Water (μg/l)	0.54			0.98				0.93		
	Sediment (μg/kg)	660			120				520		
Zinc	Water (μg/l)	14.1			12.8				15.6		
	Sediment (μg/kg)	42500			70220				78180		
p,p'-DDE	Water (μg/l)	< MDL									
	Sediment (μg/kg)	0.52			0.45				0.66		
p,p'-DDD	Water (μg/l)	< MDL									
	Sediment (μg/kg)	0.67			0.58				0.95		
p,p'-DDT	Water (μg/l)	< MDL									
	Sediment (μg/kg)	0.45			0.15				0.55		
∑ DDTs	Water (μg/l)	< MDL									
	Sediment (μg/kg)	1.64			1.18				2.16		
α-HCH	Water (μg/l)	< MDL									
	Sediment (μg/kg)	0.15			0.25				0.45		
β-HCH	Water (μg/l)	< MDL									
	Sediment (μg/kg)	0.15			< 0.05				< 0.05		
δ-HCH	Water (μg/l)	1.20									
	Sediment (μg/kg)	0.25			0.80				0.85		
∑ HCHs	Water (μg/l)	1.20									
	Sediment (μg/kg)	0.55			1.05				1.30		

μg.kg $^{-1}$ dw (dry weight)

MDL: Method Detection Limit (Copper: 0.01 μg/l; Lead: 0.25 μg/l; Cadmium: 0.01 μg/l; Zinc: 0.25 μg/l: DDTs: 0.0005 μg/l; HCHs: 0.0002 μg/l)

Appendix C5. ANALYSIS RESULTS OF CAU HAI LAGOON WATER AND SEDIMENT SAMPLES (IMOLA PROJECT)

May - 2007

Parameter	Layer	Site/Station									
		J			**K**			**L**			
		28	***29***	***30***	***31***	***32***	***33***	***34***	***35***	***36***	***37***
Temperature (^{o}C)											
pH											
Salinity ($^{0}/_{00}$)											
Transparency (cm)											
DO (mg/l)											
BOD5 (mg/l)	Surface	1.5	1.4	1.3	1.5	1.1	1.0	1.2	1.6	5.8	1.3
COD (mg/l)	Surface	3.8	8.0	6.9	4.7	5.1	4.3	4.2	3.7	21.5	2.6
Chlorophyll a(µg/l)	Surface		1.7	0.6	1.8		1.1	1.1	1.4	2.4	0.8
Total coliform (MPN/100ml)	Surface										
Fecal coliform (MPN/100ml)	Surface										
NH4/NH3-N (mg/l)	Surface	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02	<0.02
NO3-N (mg/l)	Surface	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	Bottom										
PO4-P (mg/l)	Surface	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
	Bottom										
TN (mg/l)	Surface	0.69	0.71	0.67	0.71	0.70	0.65	1.45	0.98	0.49	0.68
	Bottom										
TP (mg/l)	Surface	0.01	0.01	0.02	0.01	0.02	< 0.01	< 0.01	0.03	0.03	0.01
	Bottom										
Copper	Water (µg/l)	<0.01			106				47.8		
	Sediment (µg/kg)	394400			455800						
Lead	Water (µg/l)	0.45			0.31				7.43		
	Sediment (µg/kg)	20200			36400				37900		
Cadmium	Water (µg/l)	2.28			<0.01				0.23		

Parameter	Layer	Site/Station									
		J			**K**			**L**			
		28	***29***	***30***	***31***	***32***	***33***	***34***	***35***	***36***	***37***
	Sediment (µg/kg)	1300			100				1400		
Zinc	Water (µg/l)	8.84			9.45				13.8		
	Sediment (µg/kg)	106800			136300				120800		
p,p'-DDE	Water (µg/l)										
	Sediment (µg/kg)	2.80			0.50				0.80		
p,p'-DDD	Water (µg/l)										
	Sediment (µg/kg)	1.60			1.00				1.10		
p,p'-DDT	Water (µg/l)										
	Sediment (µg/kg)	1.10			1.80				<0.15		
∑ DDTs	Water (µg/l)										
	Sediment (µg/kg)	5.50			3.30				1.90		
α-HCH	Water (µg/l)										
	Sediment (µg/kg)	<0.05			0.30				0.50		
β-HCH	Water (µg/l)										
	Sediment (µg/kg)	<0.05			1.40				0.70		
δ-HCH	Water (µg/l)										
	Sediment (µg/kg)	1.40			1.30				1.10		
∑ HCHs	Water (µg/l)										
	Sediment (µg/kg)	1.40			3.00				2.30		

µg.kg $^{-1}$ dw (dry weight)

MDL: Method Detection Limit (Copper: 0.01 µg/l; Lead: 0.25 µg/l; Cadmium: 0.01 µg/l; Zinc: 0.25 µg/l: DDTs: 0.0005 µg/l; HCHs: 0.0002 µg/l)

Appendix D1. ANALYSIS RESULTS OF TAM GIANG LAGOON SEDIMENT SAMPLES (IMOLA PROJECT)

April - 2006

Parameter(*)		Site / Station														
		A			**B**			**C**			**D**			**E**		
		1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***
Total organic matter	(mg/g)	38.6	55.3	29.4	30.9	32.7	35.2	42.4	40.4	25.3	14.5	20.7	31.9	8.1	8.1	15.8
Lipids	(mg/g)	1.9	1.0	2.0	1.7	1.6	0.5	1.0	2.7	1.0	0.9	0.6	0.8	1.0	0.0	0.2
Carbohydrates	(mg/g)	10.2	6.4	6.9	4.9	4.6	3.5	2.8	6.3	2.4	3.0	3.9	4.1	2.3	0.6	3.0
Proteins	(mg/g)	9.0	4.5	4.5	1.0	1.6	1.3	1.9	0.9	1.7	2.3	2.1	3.7	0.1	1.5	1.5
Chlorophyll a (Chl-a)	(µg/g)	32.1	8.7	15.3	4.5	3.4	1.2	2.6	8.3	3.2	5.4	4.1	6.3	4.7	3.9	4.1
Phaeopigments	(µg/g)	50.7	25.0	29.1	12.6	9.5	6.0	6.9	17.4	8.1	9.4	6.0	20.2	10.7	2.6	10.4
Total Phytopigment (CPE)	(µg/g)	82.8	33.7	44.4	17.2	12.9	7.2	9.5	25.7	11.2	14.8	10.1	26.4	15.4	6.5	14.4
Biopolymeric carbon	(mg/g)	9.9	5.6	6.5	3.7	3.8	2.4	2.8	5.0	2.6	3.0	3.1	4.0	1.7	1.0	2.1
Biopolymeric carbon	(%)	35.7	10.1	30.7	12.1	11.6	4.84	4.65	12.3	10.1	11.3	6.18	6.97	21.53	4.06	6.15

(*) *$\mu g.g^{-1}$, $mg.g^{-1}$ dw (dry weight)*

Appendix D2. ANALYSIS RESULTS OF TAM GIANG LAGOON SEDIMENT SAMPLES (IMOLA PROJECT)

May - 2006

Parameter(*)	Site / Station														
	A			**B**			**C**			**D**			**E**		
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***
Total organic matter (mg/g)	45.0	46.0	38.4	42.6	33.7	20.8	43.0	27.1	37.8	20.1	18.9	27.9	22.5	13.0	31.1
Lipids (mg/g)	0.2	1.0	0.7	0.7	0.1	0.4	0.4	0.6	0.3	0.1	0.1	0.1	0.0	0.4	0.4
Carbohydrates (mg/g)	11.2	7.6	4.8	5.5	5.9	3.5	1.7	7.7	5.1	2.5	2.9	4.6	5.9	4.1	2.8
Protein (mg/g)	12.9	10.8	6.9	4.1	3.8	4.4	4.5	4.9	5.3	1.9	1.4	3.6	3.2	4.4	2.1
Chlorophyll a (Chl-a) (μg/g)	18.4	17.9	14.8	9.5	6.1	7.9	1.8	13.6	13.0	2.0	1.8	6.9	4.3	16.0	4.0
Phaeopigments (μg/g)	75.4	38.8	24.1	18.7	6.7	10.1	4.4	15.0	14.8	5.5	8.5	13.2	9.7	21.3	17.6
Total Phytopigment (CPE) (μg/g	93.8	56.7	38.8	28.2	12.8	18.1	6.1	28.6	27.7	7.5	10.4	20.1	14.1	37.3	21.5
Biopolymeric carbon (mg/g)	10.9	9.1	5.8	4.7	4.2	3.9	3.2	5.9	4.8	2.0	1.9	3.7	3.9	4.1	2.4
Biopolymeric carbon (%)	24.3	19.8	15.1	11.0	12.6	18.7	11.4	21.8	12.8	9.90	9.90	13.2	17.5	22.3	7.80

(*) $\mu g.g^{-1}$, $mg.g^{-1}$ dw (dry weight)

Appendix D3. ANALYSIS RESULTS OF TAM GIANG LAGOON SEDIMENT SAMPLES (IMOLA PROJECT)

August - 2006

Parameter(*)	Site / Station														
	A			**B**			**C**			**D**			**E**		
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***
Total organic matter (mg/g)	41.7	49.2	43.5	23.2	28.5	32.1	45.7	35.6	19.5	10.8	16.3	36.5	46.0	10.9	29.4
Lipids (mg/g)	1.0	0.7	0.6	0.3	0.1	0.6	0.6	0.1	0.2	0.1	0.1	0.2	0.7	0.2	0.2
Carbohydrates (mg/g)	10.6	14.5	2.2	4.0	1.5	4.2	2.3	3.3	2.5	1.3	3.3	2.5	3.5	0.6	4.7
Protein (mg/g)	10.0	13.1	7.7	7.2	4.2	4.8	6.9	2.0	5.2	1.6	2.5	6.1	7.3	2.1	6.1
Chlorophyll a (Chl-a) (µg/g)	13.7	9.2	4.2	8.5	2.8	2.8	1.9	2.4	10.5	1.7	3.1	4.5	23.4	3.6	3.5
Phaeopigments (µg/g)	26.6	21.7	12.2	8.1	5.9	13.7	7.3	10.9	15.1	3.9	5.4	15.8	31.4	2.6	12.4
Total Phytopigment (CPE) (µg/g	40.4	30.9	16.3	16.6	8.7	16.5	9.2	13.3	25.5	5.6	8.5	20.3	54.8	6.2	15.9
Biopolymeric carbon (mg/g)	9.9	12.8	5.1	5.4	2.8	4.5	4.8	2.4	3.7	1.4	2.6	4.1	5.5	1.4	5.0
Biopolymeric carbon (%)	29.6	26.0	22.0	23.1	9.75	13.9	11.5	15.4	19.2	12.5	15.9	11.4	12.1	11.6	17.1

(*) *$\mu g.g^{-1}$, $mg.g^{-1}$ dw (dry weight)*

Appendix D4. ANALYSIS RESULTS OF TAM GIANG LAGOON SEDIMENT SAMPLES (IMOLA PROJECT)

November - 2006

Parameter(*)		Site / Station														
		A			**B**			**C**			**D**			**E**		
		1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***
Total organic matter	(mg/g)	51.6	46.5	25.0	34.1	43.0	9.4	61.7	45.4	17.8	40.5	20.0	17.6	44.4	6.8	28.9
Lipids	(mg/g)	1.2	0.6	0.0	0.2	0.2	0.2	0.3	0.7	0.2	0.1	0.0	0.2	0.1	0.1	0.1
Carbohydrates	(mg/g)	1.8	1.4	3.0	1.6	6.8	5.6	6.0	1.6	3.6	4.4	0.3	3.5	1.7	0.5	2.1
Protein	(mg/g)	12.9	6.4	1.8	2.1	3.7	1.7	3.2	2.5	4.4	5.6	1.0	2.9	3.2	0.4	4.8
Chlorophyll a (Chl-a)	(µg/g)	13.6	10.1	3.1	6.5	25.5	5.3	8.1	3.7	5.0	8.6	20.3	11.0	5.5	3.9	3.3
Phaeopigments	(µg/g)	52.0	28.8	8.9	11.0	14.7	18.4	11.8	3.4	9.2	14.4	71.9	16.2	12.5	24.0	9.5
Total Phytopigment (CPE)	(µg/g	65.7	39.0	12.0	17.5	40.2	23.7	19.9	7.1	14.2	23.0	92.2	27.3	18.0	27.9	12.8
Biopolymeric carbon	(mg/g)	7.9	4.1	2.1	1.8	4.7	3.2	4.2	2.4	3.7	4.6	0.6	2.9	2.3	0.4	3.3
Biopolymeric carbon	(%)	15.3	8.86	8.30	5.27	4.95	10.3	6.81	12.0	20.8	2.85	3.22	7.84	1.97	6.10	11.2

(*) *$\mu g.g^{-1}$, $mg.g^{-1}$ dw (dry weight)*

Appendix D5. ANALYSIS RESULTS OF TAM GIANG LAGOON SEDIMENT SAMPLES (IMOLA PROJECT)

May - 2007

Parameter(*)	Site / Station														
	A			**B**			**C**			**D**			**E**		
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***
Total organic matter (mg/g)	48.1	60.7	39.6	39.2	35.7	28.0	42.7	36.6	42.3	18.9	19.8	34.9	26.7	10.5	22.6
Lipids (mg/g)	1.1	0.7	0.7	0.6	0.4	0.5	0.4	0.7	0.4	0.3	0.2	0.3	0.1	0.2	0.3
Carbohydrates (mg/g)	20.6	11.7	12.5	6.6	9.2	6.3	8.8	8.2	7.5	4.2	3.9	6.5	2.0	1.9	3.3
Protein (mg/g)	9.0	6.1	5.7	2.1	2.3	3.0	2.5	2.4	2.9	1.3	0.8	2.2	1.6	1.0	1.1
Chlorophyll a (Chl-a) (µg/g)	28.8	13.9	16.6	7.0	4.8	5.3	2.3	10.9	8.1	8.5	6.5	14.3	4.5	10.4	6.9
Phaeopigments (µg/g)	61.3	28.9	28.8	15.7	8.1	8.4	6.5	16.2	11.4	8.9	15.7	27.0	12.5	12.2	14.1
Total Phytopigment (CPE) (µg/g	90.1	42.8	45.4	22.7	12.9	13.6	8.8	27.1	19.5	17.3	22.3	41.3	17.0	22.6	21.0
Biopolymeric carbon (mg/g)	13.4	8.2	8.3	4.1	5.1	4.4	5.0	4.9	4.7	2.6	2.1	3.9	1.6	1.4	2.1
Biopolymeric carbon (%)	8.6	6.8	8.0	6.8	3.7	4.8	1.8	8.9	6.9	13.2	12.6	14.7	11.0	29.5	13.3

(*) *µg.g $^{-1}$, mg.g $^{-1}$ dw (dry weight)*

Appendix E1. ANALYSIS RESULTS OF THUY TU LAGOON SEDIMENT SAMPLES (IMOLA PROJECT)

April - 2006

Parameter(*)	Site/Station											
	F			**G**			**H**			**I**		
	16	***17***	***18***	***19***	***20***	***21***	***22***	***23***	***24***	***25***	***26***	***27***
Total organic matter (mg/g)	21.5	14.3	16.2	50.4	26.6	12.8	31.3	28.1	14.0	14.2	42.0	45.7
Lipids (mg/g)	0.5	0.2	0.2	0.9	0.5	0.5	0.7	0.1	1.1	1.0	1.3	0.8
Carbohydrates (mg/g)	4.3	2.2	3.0	5.7	3.3	1.3	6.4	4.8	5.3	3.5	4.2	8.3
Protein (mg/g)	1.6	0.5	2.2	2.0	0.5	1.3	5.5	2.8	4.0	1.6	3.4	3.6
Chlorophyll a (Chl-a) (µg/g)	18.0	3.1	8.2	39.8	3.1	10.2	11.2	4.6	5.8	6.4	3.6	4.2
Phaeopigments (µg/g)	9.7	9.2	10.0	31.2	7.9	4.0	26.5	9.0	16.4	10.9	11.5	12.6
Total Phytopigment (CPE) (µg/g)	27.6	12.3	18.2	71.0	11.1	14.2	37.8	13.6	22.2	17.2	15.1	16.8
Biopolymeric carbon (mg/g)	2.9	1.3	2.4	3.9	1.9	1.5	5.8	3.3	4.9	3.0	4.3	5.7
Biopolymeric carbon (%)	8.32	9.10	5.67	7.82	7.30	11.7	18.6	11.8	35.1	20.8	10.3	16.3

(*) *$\mu g.g^{-1}$, $mg.g^{-1}$ dw (dry weight)*

Appendix E2. ANALYSIS RESULTS OF THUY TU LAGOON SEDIMENT SAMPLES (IMOLA PROJECT)

May - 2006

Parameter(*)	Site/Station											
	F			**G**			**H**			**I**		
	16	***17***	***18***	***19***	***20***	***21***	***22***	***23***	***24***	***25***	***26***	***27***
Total organic matter (mg/g)	39.4	24.4	19.0	85.8	39.4	16.0	31.8	35.6	64.4	14.2	60.7	66.9
Lipids (mg/g)	0.5	0.3	0.5	1.4	1.1	0.4	0.2	0.1	0.6	0.1	0.3	0.3
Carbohydrates (mg/g)	7.5	4.5	6.3	10.5	4.0	1.0	4.1	4.4	6.8	2.4	7.2	8.6
Protein (mg/g)	3.0	2.7	2.0	14.3	2.8	1.0	3.6	3.7	7.4	1.5	5.6	4.3
Chlorophyll a (Chl-a) (µg/g)	9.9	3.1	4.0	58.9	2.3	1.9	11.0	7.4	10.9	3.8	11.6	9.8
Phaeopigments (µg/g)	14.5	3.9	21.7	83.4	5.2	4.6	28.1	16.0	23.2	8.4	15.5	15.1
Total Phytopigment (CPE) (µg/g)	24.4	7.0	25.7	142.3	7.5	6.4	39.1	23.4	34.1	12.2	27.2	24.9
Biopolymeric carbon (mg/g)	4.8	3.4	3.8	12.3	3.8	1.2	3.5	3.6	6.8	1.8	5.9	5.8
Biopolymeric carbon (%)	12.2	13.7	20.3	14.3	13.9	7.28	57.5	10.2	10.5	12.4	9.68	8.69

(*) $\mu g.g^{-1}$, $mg.g^{-1}$ dw (dry weight)

Appendix E3. ANALYSIS RESULTS OF THUY TU LAGOON SEDIMENT SAMPLES (IMOLA PROJECT)

August - 2006

Parameter(*)	Site/Station											
	F			**G**			**H**			**I**		
	16	***17***	***18***	***19***	***20***	***21***	***22***	***23***	***24***	***25***	***26***	***27***
Total organic matter (mg/g)	28.0	14.5	36.2	32.0	27.7	37.1	30.6	25.8	44.7	37.2	24.1	33.6
Lipids (mg/g)	0.2	0.1	0.7	0.8	0.4	0.5	0.6	0.4	1.2	0.4	0.4	0.2
Carbohydrates (mg/g)	5.9	2.5	5.4	9.3	1.9	3.1	4.4	2.6	9.0	3.7	2.9	4.6
Protein (mg/g)	3.9	3.2	10.1	9.3	4.5	3.3	6.7	3.1	2.7	5.7	5.0	4.1
Chlorophyll a (Chl-a) (μg/g)	3.4	3.3	31.4	43.1	9.2	3.4	14.9	3.6	22.1	7.0	6.0	11.8
Phaeopigments (μg/g)	34.1	11.4	40.4	53.3	7.3	4.8	34.4	13.2	24.7	12.6	2.3	12.5
Total Phytopigment (CPE) (μg/g)	37.5	14.7	71.8	96.4	16.5	8.3	49.4	16.7	46.7	19.6	8.4	24.4
Biopolymeric carbon (mg/g)	4.4	2.7	7.6	8.9	3.3	3.2	5.5	2.9	5.9	4.5	3.9	4.0
Biopolymeric carbon (%)	10.0	18.6	21.0	27.9	11.9	8.56	17.9	11.2	13.1	12.2	19.7	19.6

(*) *$\mu g.g^{-1}$, $mg.g^{-1}$ dw (dry weight)*

Appendix E4. ANALYSIS RESULTS OF THUY TU LAGOON SEDIMENT SAMPLES (IMOLA PROJECT)

November - 2006

Parameter(*)		Site/Station											
		F			**G**			**H**			**I**		
		16	***17***	***18***	***19***	***20***	***21***	***22***	***23***	***24***	***25***	***26***	***27***
Total organic matter	(mg/g)	24.1	30.1	52.5	54.7	29.0	13.5	28.5	43.8	62.9	37.7	59.3	65.1
Lipids	(mg/g)	0.1	0.1	0.2	0.8	0.6	0.6	0.3	0.3	0.7	0.2	0.8	0.7
Carbohydrates	(mg/g)	1.8	1.2	4.9	3.1	1.9	2.0	0.6	1.7	2.4	1.0	7.0	1.7
Protein	(mg/g)	7.1	4.0	14.5	9.0	3.9	2.8	4.5	4.7	8.5	3.0	9.1	8.9
Chlorophyll a (Chl-a)	(μg/g)	12.0	5.7	43.0	20.1	5.9	7.5	11.9	4.3	11.0	2.2	15.5	4.8
Phaeopigments	(μg/g)	21.9	8.8	44.6	24.8	7.2	7.3	17.8	5.3	10.2	11.6	63.9	35.6
Total Phytopigment (CPE)	(μg/g)	34.0	14.5	87.6	44.8	13.1	14.8	29.7	9.7	21.2	13.7	79.4	40.3
Biopolymeric carbon	(mg/g)	4.3	2.6	9.2	6.2	3.1	2.6	2.7	3.2	5.7	2.1	7.9	5.6
Biopolymeric carbon	(%)	17.7	8.53	17.6	11.4	10.7	19.6	9.33	7.41	8.98	5.50	9.73	14.4

(*) *$\mu g.g^{-1}$, $mg.g^{-1}$ dw (dry weight)*

Appendix E5. ANALYSIS RESULTS OF THUY TU LAGOON SEDIMENT SAMPLES (IMOLA PROJECT)

May - 2007

Parameter(*)	Site/Station											
	F			**G**			**H**			**I**		
	16	***17***	***18***	***19***	***20***	***21***	***22***	***23***	***24***	***25***	***26***	***27***
Total organic matter (mg/g)	31.0	19.4	16.8	65.7	33.0	11.4	31.5	31.8	39.2	14.2	51.4	56.3
Lipids (mg/g)	0.4	0.4	0.4	1.4	0.6	0.2	0.2	0.2	0.6	0.3	0.5	0.7
Carbohydrates (mg/g)	5.1	4.2	7.0	18.3	5.7	1.7	4.4	5.1	7.0	3.3	6.0	5.9
Protein (mg/g)	1.4	1.2	1.4	13.3	1.5	1.3	3.3	2.9	4.7	1.3	3.8	3.2
Chlorophyll a (Chl-a) (μg/g)	15.0	4.0	14.0	55.6	5.6	13.2	10.9	10.0	14.0	5.1	7.6	7.0
Phaeopigments (μg/g)	10.3	6.0	28.6	62.6	12.0	8.8	27.6	15.1	21.7	9.6	14.0	13.8
Total Phytopigment (CPE) (μg/g)	25.3	10.0	42.6	118.2	17.6	22.0	38.4	25.0	35.7	14.7	21.6	20.9
Biopolymeric carbon (mg/g)	3.0	2.6	3.8	14.9	3.5	1.4	3.7	3.5	5.6	2.2	4.7	4.5
Biopolymeric carbon (%)	20.0	6.2	14.8	14.9	6.5	36.7	11.9	11.3	10.1	9.3	6.5	6.3

(*) *μg.g $^{-1}$, mg.g $^{-1}$ dw (dry weight)*

Appendix F1. ANALYSIS RESULTS OF CAU HAI LAGOON WATER AND SEDIMENT SAMPLES (IMOLA PROJECT)

April - 2006

Parameter(*)	Site/Station									
	J			**K**			**L**			
	28	***29***	***30***	***31***	***32***	***33***	***34***	***35***	***36***	***37***
Total organic matter (mg/g)	30.8	31.2	31.2	55.1	31.6	34.4	30.2	54.1	52.8	50.3
Lipids (mg/g)	2.0	0.5	1.1	0.8	1.6	1.4	0.8	0.5	0.5	0.4
Carbohydrates (mg/g)	2.8	2.3	0.7	3.5	4.5	2.3	3.5	4.7	5.1	3.5
Protein (mg/g)	2.7	2.7	1.3	3.6	2.4	1.5	3.6	4.3	3.0	3.9
Chlorophyll a (Chl-a) (µg/g)	3.6	2.7	1.4	5.2	5.7	4.8	3.9	6.8	3.6	7.4
Phaeopigments (µg/g)	14.0	9.1	3.6	13.3	14.6	10.9	24.9	22.7	11.2	19.2
Total Phytopigment (CPE) (µg/g)	17.6	11.8	5.1	18.5	20.3	15.7	28.8	29.5	14.8	26.7
Biopolymeric carbon (mg/g)	4.0	2.6	1.7	3.7	4.2	2.7	3.7	4.3	3.9	3.6
Biopolymeric carbon (%)	12.9	8.38	5.60	6.76	13.1	7.83	12.3	8.00	10.7	7.16

(*) *$\mu g.g^{-1}$, $mg.g^{-1}$ dw (dry weight)*

Appendix F2. ANALYSIS RESULTS OF CAU HAI LAGOON WATER AND SEDIMENT SAMPLES (IMOLA PROJECT)

May - 2006

Parameter(*)	Site/Station									
	J			K			L			
	28	***29***	***30***	***31***	***32***	***33***	***34***	***35***	***36***	***37***
Total organic matter (mg/g)	37.8	38.1	38.1	49.7	36.9	38.9	62.3	80.4	40.3	57.0
Lipids (mg/g)	0.0	0.1	0.4	1.1	0.1	0.1	1.1	0.3	0.5	0.6
Carbohydrates (mg/g)	3.2	2.8	1.4	12.7	5.4	6.9	12.7	12.9	10.2	8.5
Protein (mg/g)	2.7	4.0	2.4	5.8	2.8	2.7	5.8	4.7	2.7	3.3
Chlorophyll a (Chl-a) (µg/g)	2.4	4.8	3.8	22.3	4.7	8.1	22.3	22.4	21.0	11.1
Phaeopigments (µg/g)	4.4	9.4	5.1	44.1	7.9	19.3	44.1	33.6	13.0	19.2
Total Phytopigment (CPE) (µg/g)	6.8	14.2	8.9	66.4	12.6	27.4	66.4	55.9	33.9	30.2
Biopolymeric carbon (mg/g)	2.6	3.2	2.0	8.7	3.6	4.1	8.7	7.7	5.8	5.5
Biopolymeric carbon (%)	7.00	8.29	5.34	17.6	9.66	10.6	14.0	9.54	14.3	9.66

(*) *$\mu g.g^{-1}$, $mg.g^{-1}$ dw (dry weight)*

Appendix F3. ANALYSIS RESULTS OF CAU HAI LAGOON WATER AND SEDIMENT SAMPLES (IMOLA PROJECT)

August - 2006

Parameter(*)		Site/Station									
		J			**K**			**L**			
		28	***29***	***30***	***31***	***32***	***33***	***34***	***35***	***36***	***37***
Total organic matter	(mg/g)		40.9	41.8	34.7	12.1	19.2	30.9	33.4	24.8	48.8
Lipids	(mg/g)		0.6	0.5	0.3	0.1	0.3	0.5	0.2	0.2	0.4
Carbohydrates	(mg/g)		4.6	3.1	2.6	1.0	1.7	3.4	0.5	0.4	5.2
Protein	(mg/g)		5.7	7.4	5.4	2.2	4.8	4.1	7.4	1.9	9.3
Chlorophyll a (Chl-a)	(µg/g)		11.3	9.4	3.1	2.4	4.1	7.4	5.3	2.4	6.1
Phaeopigments	(µg/g)		24.9	18.4	8.4	3.3	7.4	8.5	10.7	7.8	15.8
Total Phytopigment (CPE)	(µg/g)		36.1	27.7	11.5	5.6	11.5	15.9	16.0	10.2	22.0
Biopolymeric carbon	(mg/g)		5.1	5.2	3.9	1.5	3.2	3.7	3.9	1.3	6.9
Biopolymeric carbon	(%)	17.3	18.9	12.5	18.9	12.6	16.8	18.5	11.8	5.24	14.2

(*) *$\mu g.g^{-1}$, $mg.g^{-1}$ dw (dry weight)*

Appendix F4. ANALYSIS RESULTS OF CAU HAI LAGOON WATER AND SEDIMENT SAMPLES (IMOLA PROJECT)

November - 2006

Parameter(*)		Site/Station									
		J			**K**			**L**			
		28	***29***	***30***	***31***	***32***	***33***	***34***	***35***	***36***	***37***
Total organic matter	(mg/g)	35.1	20.3	12.8	47.6	50.3	29.7	75.8	41.0	63.5	
Lipids	(mg/g)	0.2	0.2	0.1	0.6	1.5	0.4	1.0	0.7	0.4	
Carbohydrates	(mg/g)	4.9	4.8	1.8	8.1	6.0	5.2	7.9	2.8	3.3	
Protein	(mg/g)	4.5	4.5	1.7	6.8	4.9	5.6	9.9	7.2	7.6	
Chlorophyll a (Chl-a)	(µg/g)	6.4	2.8	1.8	7.5	8.7	6.3	16.8	4.7	12.1	
Phaeopigments	(µg/g)	10.8	6.0	6.4	46.2	35.2	10.1	68.9	23.3	35.8	
Total Phytopigment (CPE)	(µg/g)	17.2	8.7	8.1	53.7	43.9	16.4	85.7	28.0	47.9	
Biopolymeric carbon	(mg/g)	4.3	4.3	1.6	7.0	5.9	5.1	8.7	5.2	5.3	
Biopolymeric carbon	(%)	12.3	21.3	12.5	24.5	21.5	17.3	8.38	12.7	13.8	

(*) *$\mu g.g^{-1}$, $mg.g^{-1}$ dw (dry weight)*

Appendix F5. ANALYSIS RESULTS OF CAU HAI LAGOON WATER AND SEDIMENT SAMPLES (IMOLA PROJECT)

May - 2007

Parameter(*)	Site/Station									
	J			**K**			**L**			
	28	***29***	***30***	***31***	***32***	***33***	***34***	***35***	***36***	***37***
Total organic matter (mg/g)		26.1	19.7		52.4	32.5	40.5	67.2	46.5	51.7
Lipids (mg/g)		0.2	0.3		0.4	0.4	0.7	0.3	0.3	0.6
Carbohydrates (mg/g)		3.7	3.5		5.1	4.2	9.2	5.5	7.0	7.9
Protein (mg/g)		2.9	2.9		2.3	3.1	3.9	2.9	2.5	4.0
Chlorophyll a (Chl-a) (μg/g)		3.9	2.6		6.2	5.3	15.6	4.8	7.3	16.3
Phaeopigments (μg/g)		11.1	4.3		10.6	14.6	34.5	16.1	15.4	36.0
Total Phytopigment (CPE) (μg/g)		14.9	7.0		16.8	19.9	50.1	20.9	22.7	52.3
Biopolymeric carbon (mg/g)		3.1	3.0		3.4	3.5	6.2	3.9	4.3	5.6
Biopolymeric carbon (%)		5.0	8.6		7.2	5.7	7.2	4.4	5.1	8.6

(*) *$\mu g.g^{-1}$, $mg.g^{-1}$ dw (dry weight)*

Appendix G1. ANALYSIS RESULTS OF TAM GIANG – THUY TU LAGOON AQUACULTURE POND WATER SAMPLES (IMOLA PROJECT)
April - 2006

Parameter	Sample							
	CAA1	CAA2	CAA3	CAA4	CAA5	CAA6	CAA7	CAA8
Temperature (^oC)	29.6	29.8	28.9	31.0	30.6	30.9	30.9	29.9
pH	9.0	8.4	8.5	8.9	9.3	7.9	8.1	8.2
EC (mS/cm)	17.5	17.3	23.8	15.2	17.3	13.1	21.6	14.4
Salinity ($^0/_{00}$)	9.9	9.8	13.9	8.5	9.8	7.3	12.4	8.0
SS (mg/l)	5	9	4	3	3	12	3	3
Turbidity (NTU)	6	10	5	3	4	14	4	4
DO (mg/l)	6.7	6.8	6.2	7.1	7.1	6.9	6.5	6.5
BOD5 (mg/l)	0.4	0.9	0.7	0.9	1.0	0.8	0.4	0.4
COD (mg/l)	11	9	13	8	11	9	13	8
NH4/NH3-N (mg/l)	0.04	0.02	< 0.02	0.05	0.07	0.03	0.02	0.04
NO2-N (mg/l)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
NO3-N (mg/l)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.05	< 0.05	0.06
PO4-P (mg/l)	0.01	0.03	0.03	< 0.01	0.01	0.01	0.01	< 0.01
TN (mg/l)	0.25	0.73	0.45	0.98	1.11	0.75	0.66	0.61
TP (mg/l)	0.03	0.05	0.05	0.02	0.04	0.03	0.03	0.02

Appendix G2. ANALYSIS RESULTS OF TAM GIANG – THUY TU LAGOON AQUACULTURE POND WATER SAMPLES (IMOLA PROJECT)
May - 2006

Parameter		Sample							
		CAA1	CAA2	CAA3	CAA4	CAA5	CAA6	CAA7	CAA8
pH		8.7	8.3	8.1	8.7	8.8	8.5	8.2	8.4
EC	(mS/cm)	37.4	34.6	30.4	33.3	36.8	35.6	34.5	36.7
Salinity	($^{0}/_{00}$)	22.8	20.9	18.6	20.1	22.3	21.4	20.7	22.2
SS	(mg/l)	5	6	12	5	8	6	8	10
Turbidity	(NTU)	5	7	13	5	9	7	9	11
DO	(mg/l)	6.3	5.6	6.1	6.4	7.1	5.3	5.8	5.1
BOD5	(mg/l)	1.1	2.0	1.6	2.7	1.5	2.3	2.4	2.3
COD	(mg/l)	9	9	9	12	713	13	12	8
NH4/NH3-N	(mg/l)	0.03	0.05	0.03	0.04	0.03	0.04	0.03	0.02
NO2-N	(mg/l)	<0.002	<0.002	0.004	0.002	0.003	0.005	0.004	0.003
NO3-N	(mg/l)	0.07	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
PO4-P	(mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TN	(mg/l)	0.53	0.51	0.39	0.51	0.61	0.38	0.17	0.25
TP	(mg/l)	0.04	0.04	0.06	0.07	0.06	0.04	0.02	0.02

Appendix G3. ANALYSIS RESULTS OF TAM GIANG – THUY TU LAGOON AQUACULTURE POND WATER SAMPLES (IMOLA PROJECT) August - 2006

Parameter		Sample							
		CAA1	CAA2	CAA3	CAA4	CAA5	CAA6	CAA7	CAA8
pH		8.2	8.0	7.9	7.8	8.0	7.8	7.5	8.0
EC	(mS/cm)	13.2	16.9	6.7	9.9	18.8	9.9	11.0	15.1
Salinity	($^0/_{00}$)	7.4	9.6	3.6	5.4	10.7	5.3	6.0	8.5
SS	(mg/l)	7	5	5	4	6	6	6	7
Turbidity	(NTU)	8	6	6	5	7	7	7	8
DO	(mg/l)	6.8	7.1	6.5	7.3	7.6	6.9	6.7	7.2
BOD5	(mg/l)	1.5	1.8	0.6	3.3	1.5	1.6	3.5	2.2
COD	(mg/l)	12	19	12	11	10	10	13	7
NH4/NH3-N	(mg/l)	0.02	0.09	0.09	0.03	0.03	0.08	0.03	0.03
NO3-N	(mg/l)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
PO4-P	(mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TN	(mg/l)	0.32	0.28	0.18	0.41	0.27	0.19	0.16	0.28
TP	(mg/l)	0.04	0.04	0.06	0.07	0.06	0.04	0.02	0.02

Appendix G4. ANALYSIS RESULTS OF TAM GIANG – THUY TU LAGOON AQUACULTURE POND WATER SAMPLES (IMOLA PROJECT)
November - 2006

Parameter	Sample							
	CAA1	CAA2	CAA3	CAA4	CAA5	CAA6	CAA7	CAA8
pH	8.6	6.4	6.6	7.2	7.4	6.9	6.6	6.7
EC (mS/cm)	2.7	0.90	2.4	4.5	3.9	0.40	0.19	0.36
Salinity ($^0/_{00}$)	1.4	0.50	1.3	2.4	2.0	0.20	0.10	0.18
SS (mg/l)	2	4	3	3	1	31	11	4
Turbidity (NTU)	2	5	4	3	1	36	12	5
DO (mg/l)	8.4	7.9	8.1	6.9	7.1	7.4	7.2	7.6
BOD5 (mg/l)	0.9	0.9	0.6	1.0	0.5	0.4	0.6	0.7
COD (mg/l)	6	5	5	6	6	6	6	10
NH4/NH3-N (mg/l)	<0.02	0.22	0.17	0.03	0.04	0.07	0.10	0.05
NO3-N (mg/l)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
PO4-P (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TN (mg/l)	0.67	1.74	1.31	0.69	1.90	1.38	2.11	1.01
TP (mg/l)	<0.01	0.02	0.04	<0.01	<0.01	0.01	0.04	0.02

Appendix G5. ANALYSIS RESULTS OF TAM GIANG – THUY TU LAGOON AQUACULTURE POND WATER SAMPLES (IMOLA PROJECT)
May - 2007

Parameter	Sample							
	CAA1	CAA2	CAA3	CAA4	CAA5	CAA6	CAA7	CAA8
pH								
EC (mS/cm)								
Salinity ($^0/_{00}$)								
SS (mg/l)								
Turbidity (NTU)								
DO (mg/l)								
BOD5 (mg/l)	2.0	2.3	2.3	1.3	1.7	0.9	1.2	1.4
COD (mg/l)	13.4	12.8	27.2	16.8	7.8	10.9	12.6	12.2
NH4/NH3-N (mg/l)	0.03	0.02	0.02	0.02	<0.02	<0.02	0.02	0.02
NO3-N (mg/l)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
PO4-P (mg/l)	0.01	0.04	0.03	0.03	0.01	0.03	0.01	< 0.01
TN (mg/l)	0.88	1.07	0.77	1.10	0.97	0.91	1.06	0.66
TP (mg/l)	0.02	0.06	0.04	0.04	0.02	0.04	0.02	< 0.01