# SURFACE WATER QUALITY IN THUA THIEN – HUE PROVINCE

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## Abstract

The surface water quality in Thua Thien – Hue was assessed through analysis of water quality parameters in Perfume river and Tam Giang - Cau Hai lagoon from 1998 to 2002. Water Quality Index (WQI) was applied to characterize Perfume river quality. The river water quality was good in term of general WQI: WM-WQI in the range of 62 – 80. Generally, most of water quality parameters of the water sources under study met Vietnam standards: the river water suitable for domestic water supply (TCVN 5942-1995) and the lagoon water met TCVN 5943-1995 for aquaculture. Problems on the surface water quality in the province were organic pollution: COD in the river and the lagoon in the range of 4 ÷ 15 mg/L and 8 ÷ 25 mg/L, respectively; eutrophication caused by phosphorous concentration at potential level (0.01 ÷ 0.03 mg P-PO4/L for the river and 0.01 ÷ 0.06 mg P-PO4/L for the lagoon); and bacterial pollution: total coliform in the river and the lagoon in the range of 2,200 ÷ 45,000 and 1,500 ÷ 46,000, respectively. Intrusion in dry season was also a problem for the river in term of domestic and irrigation use. There was no evidence on pollution of heavy metals and organochlorine pesticides in the water sources. However, $Zn^{II}$ concentration in the lagoon water (mean ≈ 23 ÷ 42 μg/L) was higher than level permitted with regard to aquaculture (according to Vietnam standard TCVN 5943-1995).

***Keywords***: Water, quality, Thua Thien – Hue.

## Introduction

Thua Thien – Hue province and its Hue city, The World Cultural Heritage, locates in Central Vietnam. Among the main surface water sources in the province, Perfume river system and Tam Giang – Cau Hai lagoon are of great importance and interest. Perfume river system (thereinafter Perfume river) originating from the mountains at the west side of the province (Truong Son mountains), flowing into the middle of Hue city, goes to the lagoon and the east sea (Pacific Ocean) through Thuan An mouth (see Figure 1). Perfume river (Song Huong) is created by 3 tributaries: two in upper section (Ta Trach and Huu Trach) and the third in lower section (Bo). Total catchment is about 3,000 $km^2$. The river flow varies from season to season. The highest flow occurs in September – November and the lowest flow occurs in March – April. The main stream from Tuan confluence to the estuary has a length of 32 km and the width and depth varying from 100 to 300 m and 2 to 18 m, respectively. Perfume river and its branches (Loi Nong, Dong Ba, Ke Van...) are relative to 42 communes and 540,000 people (63% cultivated area and 50% population of the province). The river serves about 75% water supply for uses (domestic, industrial, irrigation, tourist by boats, washing, bathing...) in Hue urban (Hop N.V., 1998; Phap T. T., 2002). Industrial development and urbanization along the river, and direct discharge of untreated wastewater into it have increased water contamination. Flood and saline intrusion is also problems for the river. Thao Long damp has been built at the lower part of the river to prevent saline intrusion in dry season (March – August). The average annual precipitation in Thua Thien – Hue province was rather high: 2,500 mm and somewhere up to 4,000 mm, and so that, flood occurred annually 3 – 4 times in Hue city. A 400,000,000 $m^3$ lake (Ta Trach lake) is being built at the upstream of the river both to lower 1 m of flood level in Hue city in rainy season (September – December and January – February) and help to prevent intrusion in dry season.

Tam Giang - Cau Hai lagoon (TG-CH lagoon) with the area of 22,000 ha, the average depth of 1.5 ÷ 2 m and the length of about 70 km along the seaside (see Figure 1) is one of the biggest lagoons in South-East Asia. It receives saline water from the sea through two mouths (Thuan An and Tu Hien) and fresh water from the rivers, inclusive of Perfume river. The lagoon is attractive and worthy of note by its biodiversity and great aquatic resources. At present, some aquatic products exploited from the lagoon are being exported to some Asian and European countries. About 300,000 residents (~ 30% population of the province) are living on aquaculture in the lagoon region. However, uncontroled exploitation of aquatic products and continous increase in cultivated area, especialy for shrimp culture, have caused much concern of degradation of biological resources and water pollution in the lagoon. Although the area for shrimp culture rose rapidly: from 40 hectare (1990) to 3,000 hactare (2002), total production of aquatic exploitation (natural catching and culture) in the lagoon was much reduced: 5000 tons/a before 1974 down to 2500 tons/a in 2001 and 2002 (Phap T. T., 2002).

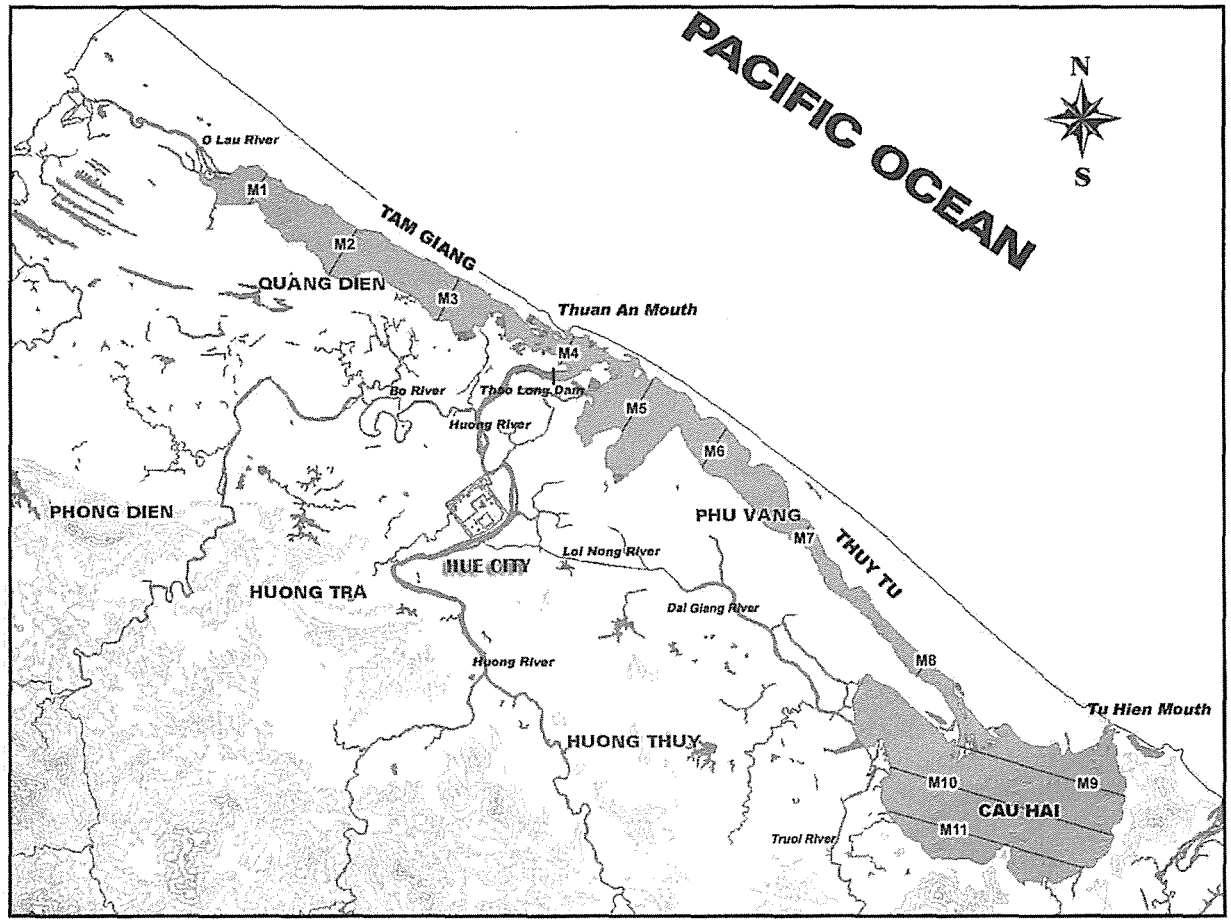



Figure 1. The map indicating Perfume river and the water sampling locations in Tam Giang – Cau Hai lagoon

Before the year of 1995, there was no remarkable studies on water quality of Perfume river and TG-CH lagoon, except some measurements of salinity and turbidity were carried out. From 1995 up till now, there are several projects relative to the water quality assessment of the waters (Hoi N. C., 1996; Hop. N.V., 1998; Phu V.V. and Hop N.V. et al., 2001). However, these projects focused mainly on analysis of major constituents and common ions. So far, there is no surface water quality monitoring program and no strategy for management of

surface water quality as well as groundwater quality. Baseline data and methodology are very necessary in the first stage of water quality management.

Water Quality Indices (WQIs) has been developed in many countries for integrated assessment of water quality for different uses (Ott W. R.,1978). General Water Quality Index (WQI) for Perfume river was established by Lieu in 1997 (Lieu P. K., 1997). The river water quality was interpreted according to WQI scale given by US_NSF (United States National Sanitary Foundation) (Ott W. R.,1978) and House and Newsome (House M. A., and Newsome D. H., 1989). However, the WQI for the river was determined in a short time (from February to April, 1997), the assessment of the river water quality was limited.

In this paper, we present the main results on analysis and assessment of the water quality of Perfume river and TG-CH lagoon in Thua Thien – Hue province. Based on the results on water quality analysis undertaken from 5/1998 to 5/2002, Water Quality Index (WQI) was also applied to characterize and assess Perfume river water quality.

## Methods

### *Sampling*

Grab samples were taken (one time each month) at 3 ÷ 4 points at each selected cross section (see Figure 1): 6 sections (S1 ÷ S6) in the main stream of Perfume river (from Tuan confluence to Thao Long damp) and 12 sections in TG-CH lagoon (M1 ÷ M4 in Tam Giang, M5 ÷ M8 in Thuy Tu and M9 ÷ M12 in Cau Hai area). Sample obtained at a sampling point was a composite one (1:1 ratio) from two sub-samples taken at 50 cm and 100 cm depth. Water sample pre-treatment and storage were carried out according to requirements for water analysis (Greeberg A. E. et al., 1985; MOSTE, 1995).

### *Analytical method*

Several water quality parameters measured at the field by potable instrument included temperature, pH, dissolved oxygen (DO), turbidity (TUR) or suspended solids (SS), total dissolved solids (TDS) or salinity (SAL). The parameters analyzed in laboratory were:

- Chemical Oxygen Demand (COD): bicromate method (Greeberg A. E. et al., 1985), spectrophotometric determination (COD was determined only in samples of salinity less than 20‰);
- Biochemical Oxygen Demand (BOD5): 5-day-incubation at 20°C (Greeberg A. E. et al., 1985); DO was measured by DO-meter;
- $NO_3$, $PO_4$, Chlorophyl- a: spectrophotometric determination (Greeberg A. E. et al., 1985); test kits were also used for field measurement and for comparison with results obtained in laboratory in many cases;
- Heavy metals were analyzed only in samples taken in 2001 and 2002:
  - $Cu^{II}$, $Pb^{II}$, $Cd^{II}$, $Zn^{II}$: anodic stripping voltammetric determination on in situ mercury film electrode (MFE) in acetate substrate (pH = 4,5 – 5) (Wang J.,1985), using standard addition method;
  - $Ni^{II}$ : adsorptive stripping voltammetry on ex situ MFE in ammonia substrate (pH = 9), using dimethylglyoxim as a ligan complexing with $Ni^{II}$;
  - $Cr^{VI}$: catalytic adsorptive stripping voltammetry on ex situ MFE in acetate substrate (pH = 5), using $NaNO_3$ as a catalyst and DTPA as a ligan complexing with $Cr^{VI}$;
  - $As^{III,V}$: anodic stripping voltammetry (ASV) for $As^{III}$ on gold film electrode in substrate solution of 1 M HCl and 0.2 mM ascorbic acid. $As^{V}$ was reduced to $As^{III}$ with KI in 4 M HCl prior to ASV;
  - Total mercury (Hg): Flameless atomic absorption spectrometry (GF-AAS) combined with digestion with bromine (Greeberg A. E. et al., 1985);
- Organochlorine pesticides (OPs): gas chromatography with ECD (Khoa N. X., 2000).

- Total coliform and fecal coliform: MPN method (Greeberg A. E. et al., 1985).

***Instrumental***

- WQA-22A (TOA, Japan) was used for field measurement.
- Instrument for COD were COD Reactor (Hach, USA) and spectrophotometer Spectronic 21D (Spectronic, USA).
- Instrument Kyoritsu, Japan was used for test kits at the field.
- Stripping voltammetry for heavy metals was carried out on polarographic analyzer 693 VA Processor (Metrohm, Switzerland). 99.999 % Nitrogen Generator (Whatman, USA) was used for de-aeration in stripping voltametric procedure.
- GF-AAS for total mercury was carried out on instrument AA-6800 combined with HVG-1 (Shimadzu, Japan).
- Instrument GC-14B (Shimadzu, Japan) with ECD was used for determination of OPs.

***Reagents***

Working solutions of metal ions ($Cu^{II}$, $Pb^{II}$, $Cd^{II}$, $Zn^{II}$, $Hg^{II}$) were prepared from 1000 ppm standard solutions (atomic absorption standard, Merck, Germany) and double-distilled water (water distiller Fistreem Cyclon, England). $HNO_3$, HCl, $CH_3COOH$ and $H_2SO_4$ solutions were Suprapur (Merck). Other reagents were prepared from the chemicals of analytical reagent grade (Merck).

***WQI calculation***

Perfume river WQI calculation was based on the procedure suggested by US-NSF. Two formulas - weighted multiplicative (WM) and weighted additive (WA) - were applied to calculate WQI for the river Ott W. R., 1978:

$$\text{WM-WQI} = \prod_{1}^{n} q_i^{w_i} \quad (2.5.1); \qquad \text{WA-WQI} = \sum_{1}^{n} q_i \, w_i \quad (2.5.2)$$

Where, $q_i$: subindex of the i th determinand, between 0 and 100, determined from subindex function for i th determinand; $w_i$: the weighting of the i th determinand, between 0 and 1; n: number of determinands in the index system (n = 9). Determinands and their weightings (written in brackets) are DO (0.17), fecal coli form (0.15), pH (0.12), $BOD_5$ (0.10), $NO_3$ (0.10), $PO_4$ (0.10), temperature (0.10), TUR (0.08) and TDS (0.08), respectively.

According to the US-NSF-WQI system, WQI score for the river under study will be zero, if concentration of any heavy metals or pesticides is higher than permissible level specified in national water quality standards.

**Results and discussion**

***Perfume river water quality***

*General survey*

Most of water quality parameters of the river met Vietnam Standard for class A of surface water (TCVN 5942-1995) (MOSTE, 1995), except COD, total coliform and fecal coliform (see Table 1). The problems to the river water quality are organic pollution, phosphorous level potential to cause eutrophication , bacterial pollution and saline intrusion.

Table 1. Summary of water quality characteristics of Perfume river (1998 – 2002) (*)

| No | Parameter | Range | Mean | TCVN 5942-1995 (**) | |
|---|---|---|---|---|---|
| | | | | A | B |
| 1 | Temperature, °C | 17 ÷ 32 | 24 | NS | NS |
| 2 | pH | 6.2 ÷ 7.8 | 7.1 | 6 ÷ 8.5 | 5.5 ÷ 9 |
| 3 | DO, mg/L | 5.0 ÷ 9.3 | 7.0 | ≥ 6 | ≥ 2 |
| 4 | BOD5 (20°C), mg/L | 0.5 ÷ 3.0 | 1 | < 4 | < 25 |
| 5 | COD, mg/L | 4 ÷ 15 | 8 | < 10 | < 35 |
| 6 | SS, mg/L | 0 ÷ 250 | 5 | ≤ 20 | ≤ 80 |
| 7 | TDS, mg/L | 0 ÷ 8,000 | 0 ÷ 30 | NS | NS |
| 8 | NO3-N, mg/L | 0.05 ÷ 0.3 | 0.02 | ≤ 10 | ≤ 15 |
| 9 | PO4-P, mg/L | 0.01 ÷ 0.03 | 0.015 | NS | NS |
| 10 | $Zn^{II}$, µg/L | 2.6 ÷ 35.6 | 18 (n = 18) | 1000 | 2000 |
| 11 | $Cu^{II}$, µg/L | 0.3 ÷ 3.9 | 2.2 (n = 18) | 100 | 1000 |
| 12 | $Pb^{II}$, µg/L | 0.3 ÷ 3.7 | 2.0 (n = 18) | 50 | 100 |
| 13 | $Cd^{II}$, µg/L | 0.04 ÷ 0.25 | 0.14 (n = 18) | 10 | 20 |
| 14 | $Ni^{II}$, µg/L | 0.7 ÷ 1.3 | 1.1 (n = 18) | 100 | 1000 |
| 15 | $As^{III,V}$, µg/L | ND | < 5 (n = 5) | 50 | 100 |
| 16 | $Cr^{VI}$, µg/L | ND | < 5 (n = 5) | 50 | 50 |
| 17 | $Hg^{II}$, µg/L | ND | < 1 (n = 5) | 1 | 2 |
| 18 | DDTs, µg/L | ND | < 0.1 (n = 5) | 10 | 10 |
| 19 | Total coliform, MPN/100 mL | 2,200 ÷ 45,000 | 12,000 | 5,000 | 10,000 |
| 20 | Fecal coliform, MPN/100 mL | 110 ÷ 450 | 190 | NS | NS |

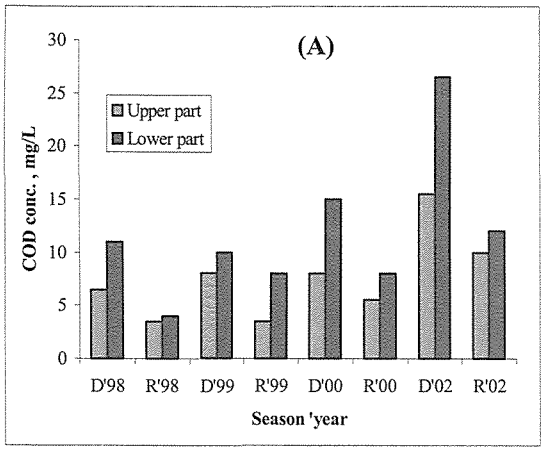
(*) The results obtained from analysis of samples taken in surface layer (50 – 100 cm depth).

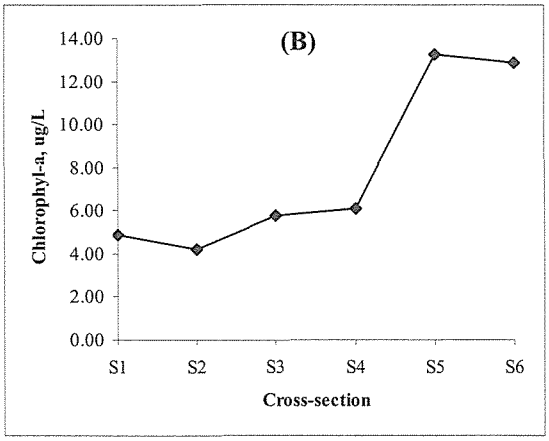
(**) Values in the column A are applied to the surface water using for source of domestic water supply with appropriate treatments; Values in the column B are applied to the surface water using for the purposes other than domestic water supply. Quality criteria of water for aquatic life are specified in a separate standard.

NS: Non-specified ; ND: Non-determined.

- *Organic pollution* was shown through COD concentration (see Figure 2A). The pollution was increased from 1998 to 2002 and higher in dry season than in rainy season. Untreated wastewaters discharged directly into the river reach passing Hue city increased organic pollution in the lower part (sections S4, S5, S6) of the main stream of Perfume river (see figure 2A).
- *PO4-P concentration* in the river water was in the range of 0.01 ÷ 0.03 mg/L and increased in rainy season. This concentration may cause eutrophication in the river. In fact, that was confirmed by the results of algae analysis (about 40,000 ÷ 3,000,000 cells/$m^3$) and chlorophyl-a analysis (see Figure 2B). A water source having concentration of chlorophyl-a over 2.5 µg/L is at eutrophycation condition (Chapman D., 1992).
- *Bacterial pollution* occurred not only for Perfume river, but also for the rivers in other part of Vietnam. The pollution of coliforms caused by untreated wastewaters, direct defecation and other activities from residents living along river banks and from "floating communities" on the river.
- *Saline intrusion* occurred in dry season, normally up to the first water intake (Van Nien) of Water Treatment Plant in Hue city. In August, 2002, saline intrusion was abnormally up to Tuan confluence. This caused difficulties for domestic and irrigation water supply. Saline stratification was also found (see Figure 2C) between surface layer (50 ÷ 100 cm depth) and bottom layer (50 cm from the bed of river).

  For the Perfume river's branches, which have their flow less than that of the river, the problems on organic pollution, eutrophication and bacterial pollution was more serious.



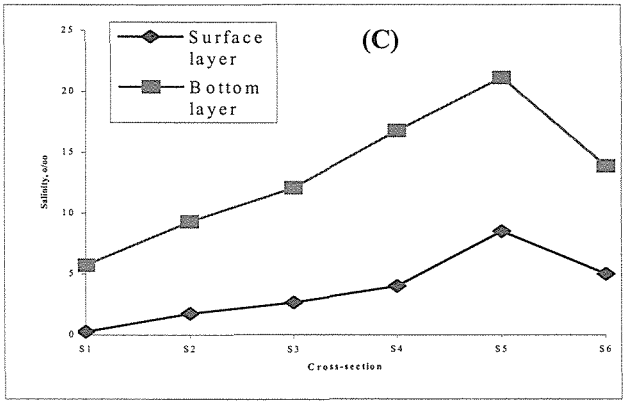




Figure 2.

**(A).** COD variation of upper and lower part of Perfume river in dry (D) and rainy (R) season of 1998 –2002

**(B).** Chlorophyl-a (μg/L) variation in Perfume river - from S1 to S6 cross section (May, 2002)

**(C).** Saline stratification in Perfume river in dry season of 2002

***Water Quality Index (WQI)***

WQIs for each cross section of the river were calculated using average values of water quality parameters (determinands) over the time period of sampling. Two formulas (WA-WQI and WM-WQI) were applied to computed WQIs for the river. From Table 2 and Figure 3, it can be seen that:

- Average WQIs of the river were in the score range from 62 ÷ 80 and the difference between WQIs was not significant. According to NSF-WQI's classification for WA-WQI and WM-WQI (Ott W. R., 1978), most of WQIs of the river (about 70 %) achieved class II with the "good" water quality (WQI score range of 71 ÷ 90). According to House and Newsome (House M. A. and Newsome D. H., 1989), with this quality level, the river water is potential to use for potable supply with "minor purification", i.e. simple physical treatment and disinfection, for "industries requiring high quality water". It is "suitable for all fish species, agricultural use and recreational purpose". However, several WQIs (about 30%) at lower part of the river only met class III with the "moderate good" water quality (WQI score range of 61 ÷ 70). With this quality, generally the river water is still suitable for above purposes, except for game and salmon fish (House M. A. and Newsome D. H., 1989).
- The significant contribution of high-weighted determinands was reflected in WM-WQI better than in WA-WQI.
- General water quality of the river in terms of WQI decreased from upstream to downstream and was in dry season worse than in rainy season.

Table 2. Average WM-WQIs at the cross sections of Perfume river from 1998 to 2002

| Year | Cross section | | | | | |
|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S4 | S5 | S6 |
| 1998 | 78 | 76 | 76 | 73 | 68 | 68 |
| 1999 | 74 | 72 | 62 | 69 | 66 | 67 |
| 2000 | 74 | 73 | 71 | 70 | 66 | - |
| 2001 | 76 | 76 | 72 | 72 | 65 | 66 |
| 2002 | 79 | 79 | 79 | 76 | 78 | 75 |

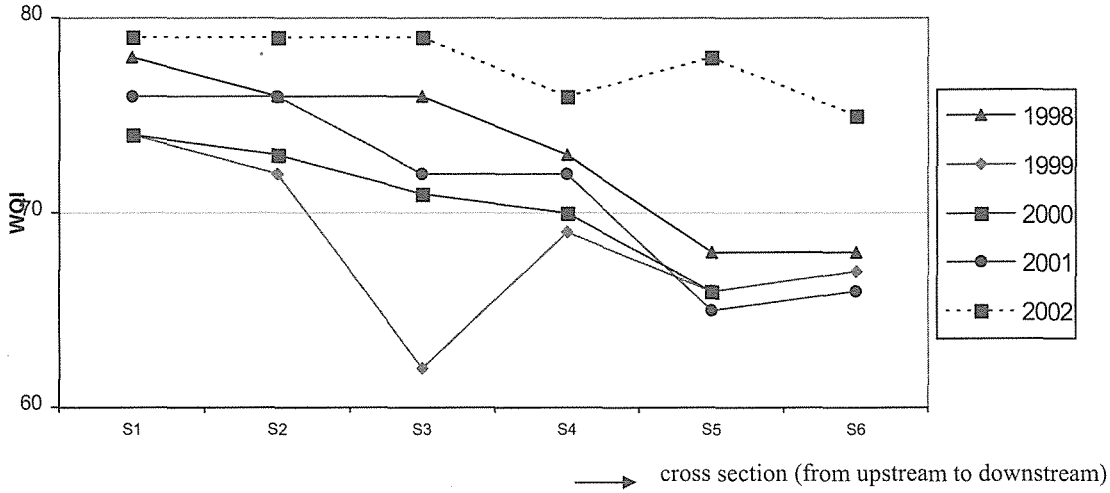



Figure 3. Variation of Perfume river WM-WQIs (1998 ÷ 2002)

***TG - CH lagoon water quality***

- *Temperature* of the lagoon water was in the range of 15 ÷ 35°C. Temperature stratification between surface and bottom layer was not significant (< 1 °C).
- *pH* range of the water was 6.0 ÷ 8.4. Because of impact of sea water, pH was at the places near Thuan An and Tu Hien mounth (about 7.7 ÷ 8.3) higher than at other places. This range of pH met requirement for aquaculture (according to Vietnam standard TCVN 5943-1995 for coastal water quality).
- *Suspended solids (SS) and dissolved oxygen (DO)* of the lagoon water were in the range of 0 ÷ 30 and 4.8 ÷ 9.5 mg/L, respectively. DO mean and standard deviation in the water was (6.6 ± 0.9) mg/L. Generally, SS and DO variation was not be well predicted, because impact of natural (wind, wave, flow, runoff...) and artificial (aquaculture, boating, catching...) was rather complex. However, that SS and DO of the lagoon water met regulations for aquaculture (according to TCVN 5943-1995).
- *Salinity* of the lagoon water was in the range of 0 ÷ 32.2 ‰ and depended on the factors such as tide, flow, precipitation... Much decrease of the salinity in the whole lagoon in rainy season (see Figure 4) made difficulties for aquaculture of brackish species. The historical flood occured in November, 1999 opened a new mouth (Hoa Duan mouth with 400 m width between section M4 and M6) and then increased salinity. Shrimp culture, therefore, gained high production in dry season of 2000. After Hoa Duan mouth was closed in August, 2000 salinity of the lagoon water decreased. Saline stratification occurred more usually in Tam Giang and Cau Hai area than in Thuy Tu, where water exchange with the sea was easier through two mouth (Thuan An and Tu Hien). The salinity difference between surface and bottom layer at the place near Thuan An mouth (section M4) was about 5 ÷ 15 ‰.

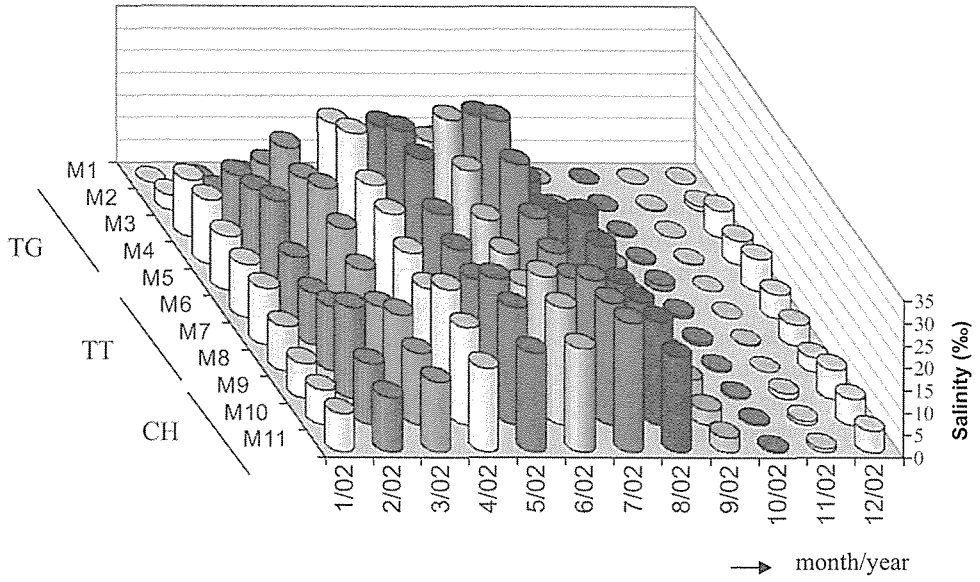



Figure 4. Salinity variation in Tam Giang – Cau Hai lagoon in 2002
(TG, TT, CH: Tam Giang, thuy Tu, Cau hai area, respectively; see figure 1)

- *Heavy metals* ($Cu^{II}$, $Pb^{II}$, $Cd^{II}$, $Zn^{II}$): heavy metal level in the lagoon water was low (see Table 3) and therefore, met requirement for aquaculture (according to TCVN 5943-1995), except $Zn^{II}$. We think that routine monitoring of $Zn^{II}$ in the lagoon water is necessary.

Table 3. Concentration of $Cu^{II}$, $Pb^{II}$, $Cd^{II}$ and $Zn^{II}$ in the TG-CH lagoon in 2001 and 2002

| Area | | $Cu^{II}$ (µg/L) | $Pb^{II}$ (µg/L) | $Cd^{II}$ (µg/L) | $Zn^{II}$ (µg/L) |
|---|---|---|---|---|---|
| Tam Giang – Thuy Tu (M1 ÷ M8) | Mean | 2,2 – 3,3 | 2,0 – 2,2 | 0,14 – 0,28 | 23,3 – 36,9 |
| | Range | 0,43 – 11,7 | 0,51 – 4,8 | 0,03 – 0,85 | 11,9 – 97,2 |
| Cau Hai (M9 ÷ M11) | Mean | 2,6 – 3,0 | 2,4 – 2,9 | 0,15 – 0,30 | 28,3 – 41,7 |
| | Range | 0,28 – 7,3 | 0,58 – 5,7 | 0,04 – 0,82 | 13,3 – 127 |
| TCVN 5943 - 1995 (*) | A | 10 | 50 | 5 | 10 |
| | B | 20 | 100 | 10 | 100 |

(*) Class A is applied to aquacultutre; class B is applied to other purposes (MOSTE, 1995)

- *Pesticides*: The results on analysis of organochlorine pesticides in 315 water samples taken in the lagoon from 1998 to 2000 shown that (N.X.Khoa, 2000):
  - Ultra-trace DDTs and HCHs were found in the lagoon water.
  - Levels of DDTs and HCHs in the the lagoon water were 7 ÷ 90 ppt and < 5 ppt, respectively.

- *Problems*: Like Pefume river, problems to the lagoon water quality were also organic pollution, concern about eutrophycation caused by potential phosphorous level and bacterial pollution.
  - Increase in organic pollution (see Figure 5) can be mainly caused by rapid development of aquaculture, espescialy shrimp culture in recent years.
  - Although NO3-N concentration in the water was low, from 0.05 ÷ 0.57 mg/L, PO4-P concentration was at level of 0.01 ÷ 0.06 mg/L, that may cause eutrophycation. This was confirmed by the results of

chlorophyl-a analysis (range: 4 ÷ 131 μg/L; mean: 10 ÷ 30 μg/L). In rainy season, runoff and drainage introduced more phosphorous into the lagoon and therefore, PO4-P level was increased.

- Bacterial pollution: Total coliforms and fecal coliform in the lagoon water were 1,500 ÷ 46,000 MPN/100 mL and 0 ÷ 15,000 MPN/100 mL, respectively, higher than level permitted (according to TCVN 5943-1995 for aquaculture purpose: limited value of total coliforms ≤ 1,000 MPN/100 mL). Obviously, bacterial pollution has caused much concern about reduction in the aquaculture production in the lagoon region. This may bring about adverse impact to sustainable development in the region.

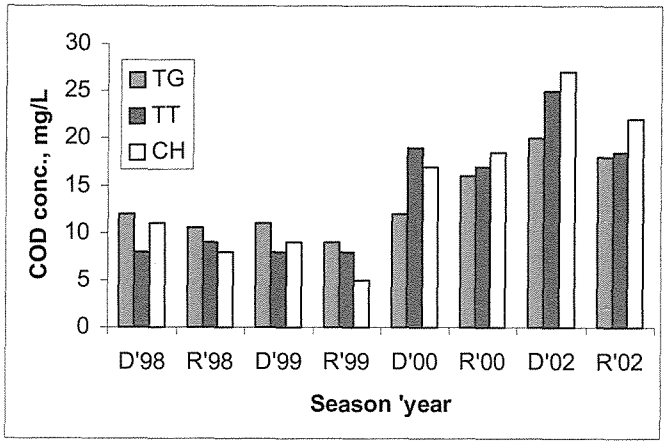



*Figure 5.* COD variation in TG-CH lagoon water in dry (D) and rainy (C) season in 1998 - 2002

## Conclusion

The water quality of Perfume river and Tam Giang – Cau Hai lagoon in Thua Thien Hue province was good with regard to most of basic water quality parameters. Problems on the water quality in the province were organic pollution, eutrophycation caused by potential phosphorous level and bacterial pollution. These may reduce the aquaculture production and influence sustainable development in the lagoon region. For Perfume river, intrusion was also an adverse impact to water quality for domestic and irrigation use. The use of WQI allowed to assess intergratedly water quality of the river. WM-WQI was identified the best one to use for characterization of the river water quality.

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