

Chapter 2 Hydrological survey

2 - 1 Objective

During the Phase , hydrological survey was carried out both during the dry and rainy season. The analysis result of dry season was analyzed already in the Phase reports. But result of rainy season was not reported for limitation of analysis period. At Phase , supplementary survey additional of 10 point was carried out. The results of rainy season were analyzed with results of both the dry and rainy season together.

2 - 2 Result of the rainy season survey

2-2-1 Survey methods

(1) Periods of the survey

Period of field survey of rainy season is as follows;

: 20th Jan. 2003 – 1st Feb. 2003 1 time

(2) Point of the survey

The survey points are identical positions taken during the dry season. (Location of the survey points is shown in Fig.II-2-1.)

(3) Field measuring method and sampling methods for water quality

Field measuring method and sampling methods were the same as taken during the dry season.

2-2-2 Duplication Sample

The duplication samples were sampled at 8 points, which were selected from 80 regular sampling points at random, and were analyzed by the same method as for regular samples. The result is shown in Appendix 3. Good correlation can be seen between the regular samples and the duplication samples in pH, electric conductivity and major dissolved composition. While, in some minor elements, correlation cannot be seen at near LOD value such as Cu and As. Correlation cannot be seen at above LOD value such as Cr and Zn.

2-2-3 Characteristic of river water quality

In each sampling point, temperature of atmosphere, water pH, water temperature, electric conductivity, Dissolved Oxygen (DO) and turbidity of river water were measured. The chemical components in accordance with Australian drinking water guideline (ADWG) were analyzed at ALS Environments Co. in Australia. Results of site measurement of river water and chemical analyses of dissolved composition were shown in Appendix 4, while statistical data for every river systems were shown in Appendix 5.

(1) Characteristic of physical description of river water

River flow:

The smallest river flow was 0.0 m³/sec., while the largest river flow was 255 m³/sec. The average of the river flow was 25.5 m³/sec.

Water temperature:

The rivers water temperature showed the lowest value of 22.2 and the highest value of 30.5 . The average of the whole survey points was 25.7 and is approximately 3 lower than atmospheric temperature (28.9).

Turbidity:

The turbidity showed the lowest value of 0mg/l and the highest value of 333mg/l at point 58W in lower reaches of the Sigatoka River. There is difference of turbidity of water among river systems.

Electric conductivity:

Electric conductivity of the river water showed the lowest value of 3.4 mS/m at point 4W in an upper reaches of the Rewa River, the highest value of 22.4 mS/m at point 56W in the middle reaches of the Sigatoka River and the mean of 9.18mS/m. There was such a tendency that electric conductivity differs depending on water system. For example, average of electric conductivity was 15.44 mS/m in the Sigatoka River System compared to 7.14 mS/m ~ 8.65 mS/m in the other river. .

(2) Characteristic of composition and composition ratio of dissolved components**pH:**

pH showed the minimum of 6.10 at point 42W seeping water in the Rewa River, while the maximum of 8.12 at point 59W and the mean of 7.38. These river waters indicated variation from weak acidity, neutrality to weak alkaline. There was a tendency where pH differs depending on water system, for example, pH 7.73 in the Sigatoka River system and pH 7.11 - 7.75 in other river.

DO (Dissolved Oxygen):

DO showed the minimum of 4.40 mg/l at point 51W in an upper reach of the Rewa River, while the maximum of 14.1 mg/l at point 52W in an upper reach of the Rewa River system and average of 7.53 mg/l. The difference between water system was not confirmed.

COD (Chemical Oxygen Demand):

COD showed the minimum of <1.0 mg/l at point 5W, 10W of the Rewa River system, while the maximum of 62.0 mg/l at point 63W of an upper reach of the Sigatoka River system and an average of 18 mg/l. COD of the Sigatoka River water system was 39mg/l. Indicating higher value compared with the other river system.

Hardness:

Hardness showed wide range of value with the minimum of 12 mg/l at point 4W in the Rewa River system, while the maximum of 115 mg/l at point 56W in the Sigatoka River system.

The average values in each separated river system were 25.0 mg/l for the Rewa River system, showing the highest of value 69 mg/l for the Sigatoka River system compared to 35 mg/l for The Navua River system.

Major dissolved composition:

Stiff diagrams for river waters were shown in Fig. II-2-2.

As for anions, the shapes of the stiff diagrams for 4 river systems including the Rewa River, the Navua River, the Sigatoka River and the Coastal rivers are spear type and show that the HCO₃ is abundant. As for cations, the shapes of the stiff diagrams for the Sigatoka River are spear type and show that the Ca is abundant. The difference in the cation quantities is not seen

in the Rewa River, The Navua River and the Coastal rivers. Grasping the total concentration of the major components from the shape of the diagrams, the total concentration of the Sigatoka River is higher than the other 3 rivers.

Piper plots of river water composition are shown in Fig. II-2-3.

As for the anion of river water in this survey area, HCO_3 is higher than $(\text{Cl}+\text{SO}_4)$ at almost all points. As for the cation, $(\text{Ca}+\text{Mg})$ is higher than $(\text{Na}+\text{K})$. Generally, all 4-river systems in the survey area belong to II Carbonate Hardness territory, and are of a circulating characteristic supply type surface water of the unconfined groundwater.

(3) Characteristic of minor components of river water

Elements such as Al, As, Cr, Cu, Pb and Zn were detected at all surveyed points. The cumulative probability plots for them were drawn as shown in Fig. II-2-4. Threshold values from critical point were analyzed and the concentration maps were drawn as shown in Fig. II-2-5. Concentrations of each minor component are mentioned below.

1) Components undetected

Such as elements Sb, Hg, N (NO_2) and Sulphide were not detected at any points.

2) Components detected at some points

Silver (Ag):

The results of Ag were above the Lower Limit of Reporting (LOR) (0.001 mg/l) at 4 points (1W, 11W, 41W, and 45W) in the Rewa River system, at 2 points (21W, 31W) in the Navua River system, and at 1 point (61W) in the Sigatoka River system

Boron (B):

The results of B were above the LOR (0.1 mg/l) at 3 points (6W, 33W, 48W) in the Rewa River system, 6 points (27W, 28W, 29W, 30W, 31W, 32W) in the Navua River system and, 2 points (53W, 64W) in the Sigatoka River system.

Cyanide (CN):

The results of CN were above the LOR (0.001 mg/l) at 1 point (46W) in the Rewa River system at 1 point (69W) in the Sigatoka Rivers, and at 1 point (75W) in the coastal rivers.

Fluorine (F):

The results of F were above the LOR (0.1 mg/l) at 2 points (51W, 52W) in the Rewa River system, at 1 point (20W) in the Navua River system, at 19 points (53W-71W) in the Sigatoka Rivers, and at 2 points (72W, 73W) in the coastal rivers. F was detected at many points of the Sigatoka River system.

Molybdenum (Mo):

The results of Mo were above the LOR (0.001 mg/l) at 1 point (9W) in the Rewa River system and at 3 points (59W, 64W, 68W) in the Sigatoka River system.

Lead (Pb):

The results of Pb were above the LOR (0.001 mg/l) at 10 points (4W, 59W, 10W, 12W, 13W, 15W, 17W, 34W, 51W, 52W) in the Rewa River system, at 3 points (25W, 26W, 27W) in the Navua River

system, at 1 point (58W) in the Sigatoka River system, and at 1 point (73W) in the Coastal River system.

Selenium (Se):

The results of Se were above the lower limit of reporting (LOR) 0.01 mg/l at 1 point (50W) in the Rewa River system, at 5 point (53W, 56W, 57W, 62W, 68W) in the Sigatoka River system and at 2 points (76W, 80W) in the Coastal River system.

3) Components detected in the whole area

Iron (Fe):

Fe was detected widely in the survey area, while it was below the LOR (0.01 mg/l) at some points. The highest value was 3.37 mg/l in the Rewa River system (point 15W) and the mean 0.154 mg/l. For a threshold value designated as 0.2 mg/l, the points that show above the threshold value were recognized in the Rewa River system (points 10W, 15W, 26W, 34W, 36W), the Sigatoka River system (points 58W, 69W).

Aluminium (Al):

Al was detected widely in the survey area, while it was below the LOR (0.01 mg/l) at some points. The highest value was 2.93 mg/l in the Rewa River system (point 34W) and the mean 0.188 mg/l. For a threshold value designated as 0.2 mg/l, the points that show above the threshold value were recognized in the Rewa River system (points 4W, 15W, 34W, 36W), the Navua River system (points 24W, 26W, 27W), and the Sigatoka River system (points 58W).

Arsenic (As):

As was detected widely in the survey area, while it was below the LOR (0.001 mg/l) at some points. The highest value was 0.006 mg/l in the Rewa River system (point 36W) and in the Navua River system (point 27W) and the mean 0.017 mg/l. For a threshold value designated as 0.004 mg/l, the points that show above the threshold value were recognized in the Rewa River system (points 15W, 34W, 36W, 37W, 38W, 48W), the Navua River system (points 21W, 27W), and the Sigatoka River system (points 58W, 64W).

Barium (Ba):

Ba was detected widely in the survey area, while it was below the LOR (0.001 mg/l) at some points. The highest value was 0.02 mg/l in the Rewa River system (point 15W) and the mean 0.0037 mg/l. For a threshold value designated as 0.008 mg/l, the points that show above the threshold value were recognized in the Rewa River system (points 5W, 10W, 15W, 17W, 37W, 42W), and the Navua River system (points 20W, 26W).

Chromium (Cr):

Cr was detected widely in the survey area, while it was below the LOR (0.001 mg/l) at some points. The highest value was 0.261 mg/l in the Rewa River system (point 36W) and the mean 0.0165 mg/l. For a threshold value designated as 0.006 mg/l, the points that show above the threshold value were recognized in the Rewa River system (points 4W, 17W, 34W, 36W, 44W, 47W, 48W, 49W) and the Sigatoka River system (points 56W, 57W).

Copper (Cu):

Cu was detected widely in the survey area, while it was below the LOR (0.001 mg/l) at some points. The highest value was 0.037 mg/l in the Rewa River system (point 15W) and the mean 0.0022 mg/l. For a threshold value designated as 0.005 mg/l, the points that show above the threshold value were recognized in the Rewa River system (points 9W, 12W, 15W, 34W, 42W), and in the Sigatoka River system (points 55W, 56W, 57W).

Manganese (Mn):

Mn was detected widely in the survey area, while it was below the LOR (0.001 mg/l) at some points. The highest value was 0.098 mg/l in the Rewa River system (point 15W) and the mean 0.0134 mg/l. For a threshold value designated as 0.03 mg/l, the points that show above the threshold value were recognized in the Rewa River system (points 3W, 15W), the Navua River system (points 26W), the Sigatoka River system (points 53W, 56W, 57W) and the Coastal River system (points 72W, 73W, 80W)

Nickel (Ni):

Ni was detected widely in the survey area, while it was below the LOR (0.001 mg/l) at some points. The highest value was 0.02 mg/l in the Sigatoka River system (point 56W) and the mean 0.0023 mg/l. For a threshold value designated as 0.008 mg/l, the points that show above the threshold value were recognized in the Rewa River system (points 34W, 36W, 47W), the Navua River system (points 24W, 27W), and the Sigatoka River system (points 55W, 56W, 70W, 71W).

Zinc (Zn):

Zn was detected widely in the survey area, while it was below the LOR (0.001 mg/l) at some points. The highest value was 0.492 mg/l in the Sigatoka River system (point 55W) and the mean 0.0502 mg/l. For a threshold value designated as 0.15 mg/l, the points that show above the threshold value were recognized in the Rewa River system (points 3W, 15W, 16W, 41W), and the Sigatoka River system (points 55W, 56W, 58W).

Ammonia as Nitrogen (N (NH₃)):

N (NH₃) was detected widely in the survey area, while it was below the LOR (0.01 mg/l) at some points. The highest value was 0.1 mg/l in the Rewa River system (point 12W) and the mean 0.029 mg/l. For a threshold value designated as 0.05 mg/l, the points that show above the threshold value were recognized in the Rewa River system (points 1W, 12W, 46W), the Sigatoka River system (points 71W) and the Coastal River system (points 77W, 79W, 80W)

Nitrate as Nitrogen (N (NO₃)):

N (NO₃) was detected widely in the survey area, while it was below the LOR (0.01 mg/l) at some points. The highest value was 0.26 mg/l in the Sigatoka River system (point 58W) and the mean 0.034 mg/l. For a threshold value designated as 0.12 mg/l, the points that show above the threshold value were recognized in the Rewa River system (points 37W), the Sigatoka River system (points 55W, 58W, 60W, 62W, 63W, 65W, 66W) and the Coastal River system (point 73W)

Phosphorus (P):

P was detected widely in the survey area, while it was below the LOR (0.01 mg/l) at some points. The highest value was 1.06 mg/l in the Rewa River system (point 38W) and the mean 0.043 mg/l. For a threshold value designated as 0.06 mg/l, the points that show above the threshold value were recognized in the Rewa River system (points 3W, 7W, 15W, 34W, 38W, 40W, 50w), the Navua River system (point 26W), and the Sigatoka River system (points 58W, 60W).

2-2-4 Discussions of the result of the rainy season survey

(1) Feature of river water

The electric conductivity differs between each drainage system. The average conductivity is 7.14 mS/m in the Rewa River system, while 15.44 mS/m in the Sigatoka River system. The pH also differs between each drainage system with the average pH 7.16 in the Rewa River system, compared that of the Sigatoka River system is 7.73

In general, Na, K, Ca, Mg, HCO₃, CO₃, SO₄ are the major dissolved constituents of the surface water. We found that the presence and ratio of these components are different between river systems. For example, as for the anion (HCO₃) is dominant in all river systems, and as for the cation (Ca) is dominant in the Sigatoka River system while no large difference of the cation presence is seen in the Rewa River system, the Navua River system and the Coastal rivers. The Sigatoka River system shows higher total concentration of the major cations and anions in comparison with the other 3 river systems. This may be a primary factor that raises electric conductivity and pH. Furthermore, the cause and why the presence of Ca and HCO₃ are high in the Sigatoka River system is thought to be influence of sedimentary rocks such as limestones existence along the Sigatoka River system. Although presence and ratio of some components somewhat differ among the survey area, the general feature of the river water of this survey area shows neutral pH, Ca as principal cation and HCO₃ as principal anion. Such water as rich in alkaline-earth carbonate is thought to be circulating free groundwater.

(2) Comparison with water quality standards

The chemical compositions of the river water of the survey area were compared with the regulation value of Australian Drinking Water Guidelines (ADWG). As a result, the following number of samples showed the high values in comparison with ADWG.

Al: 8 points (4W, 15W, 24W, 26W, 27W, 34W, 36W, 58W)

As: 1 point (64W)(Hot spring)

Cr: 8 points (4W, 24W, 27W, 34W, 36W, 44W, 47W, 48W, 56W)

Fe: 4 points (10W, 15W, 26W, 69W)

Ni: 1 point (56W)

Pb: 3 points (27W, 52W, 58W)

Se: 8 points (50W, 53W, 56W, 57W, 62W, 68W, 76W, 80W)

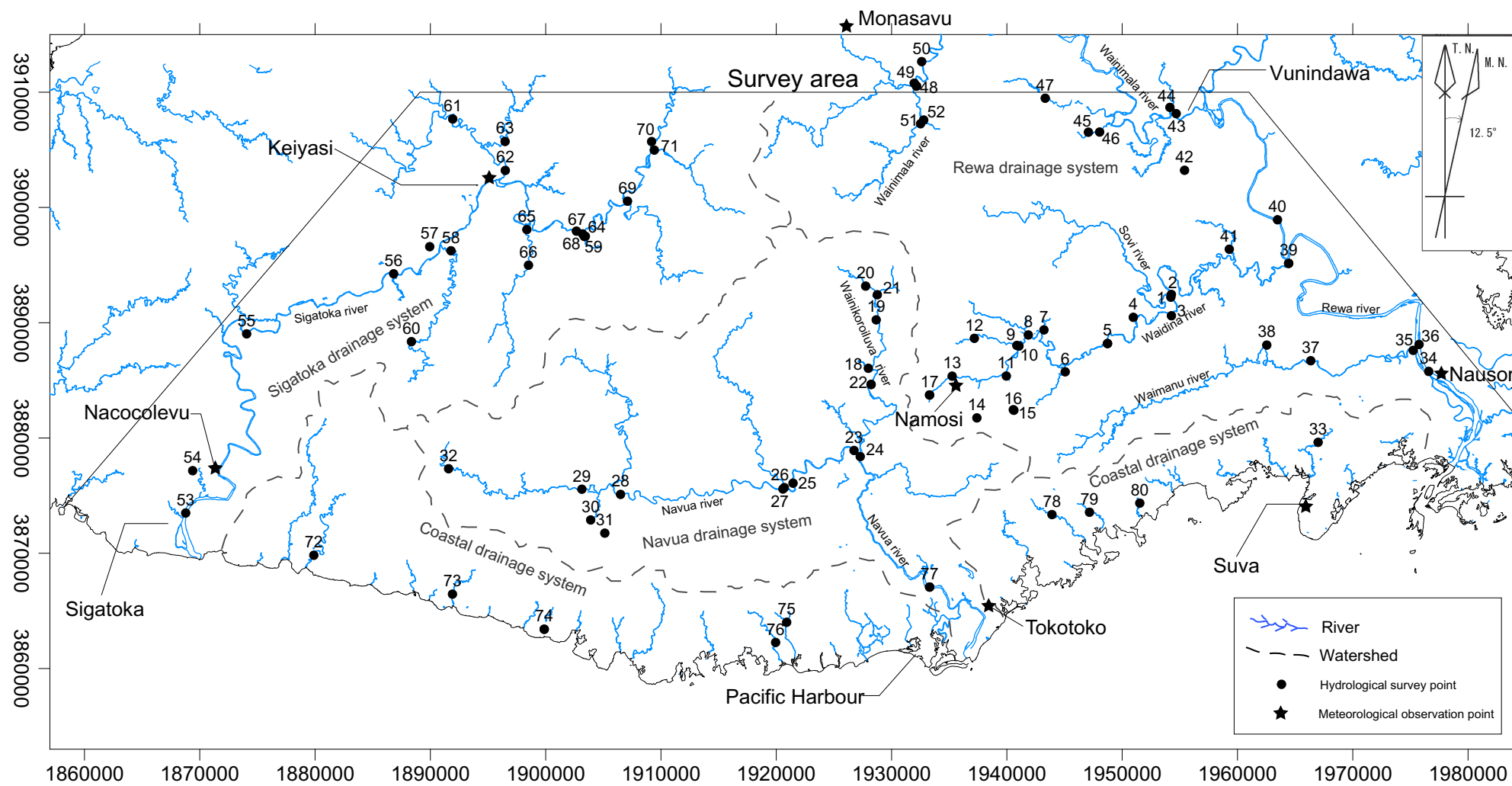


Fig.II-2-1 Sampling location of the surface water samples (1:500,000)

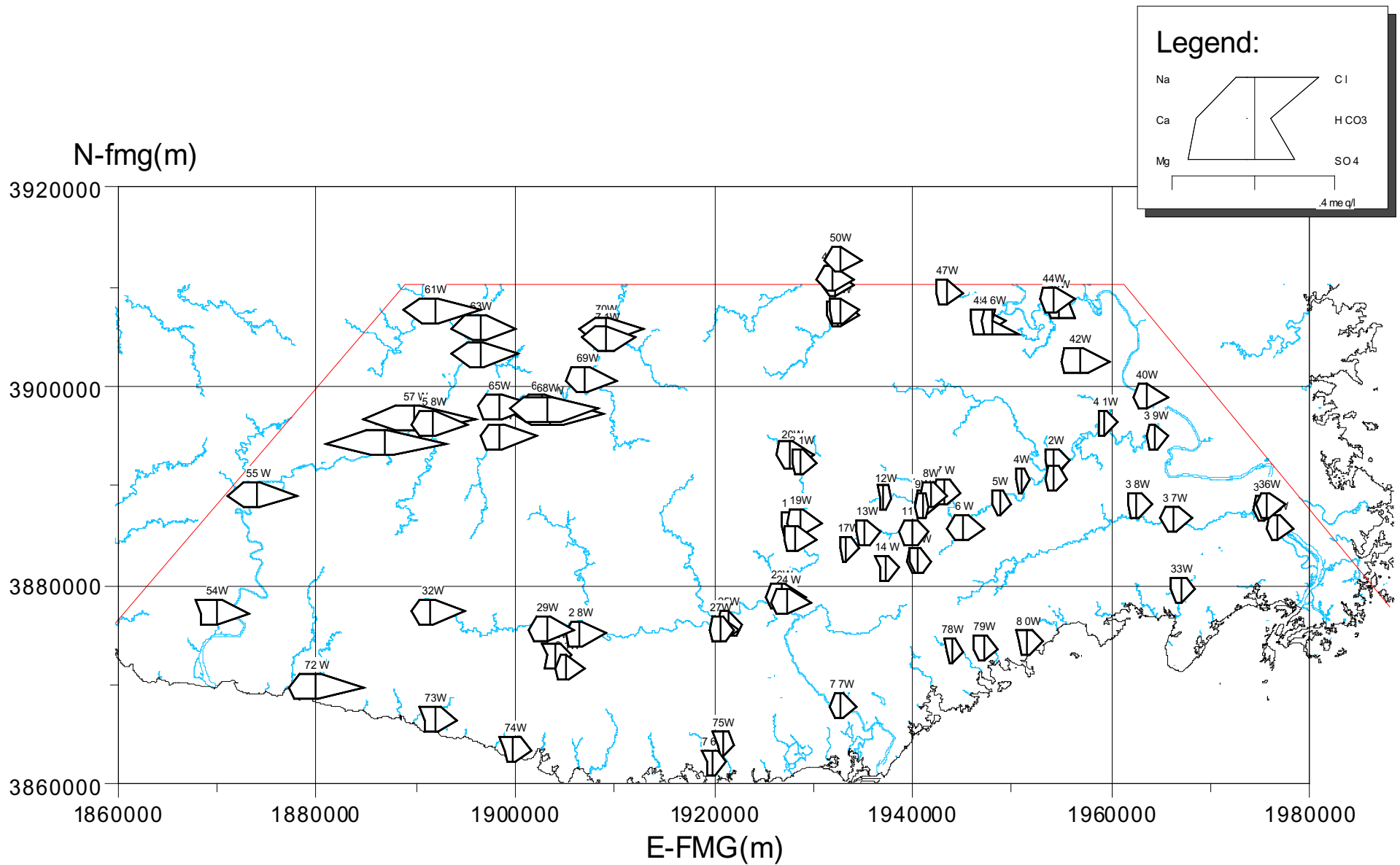


Fig11-2-2 Stiff diagrams of the surface water chemical compositions (Rainy Season)

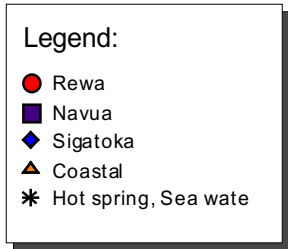
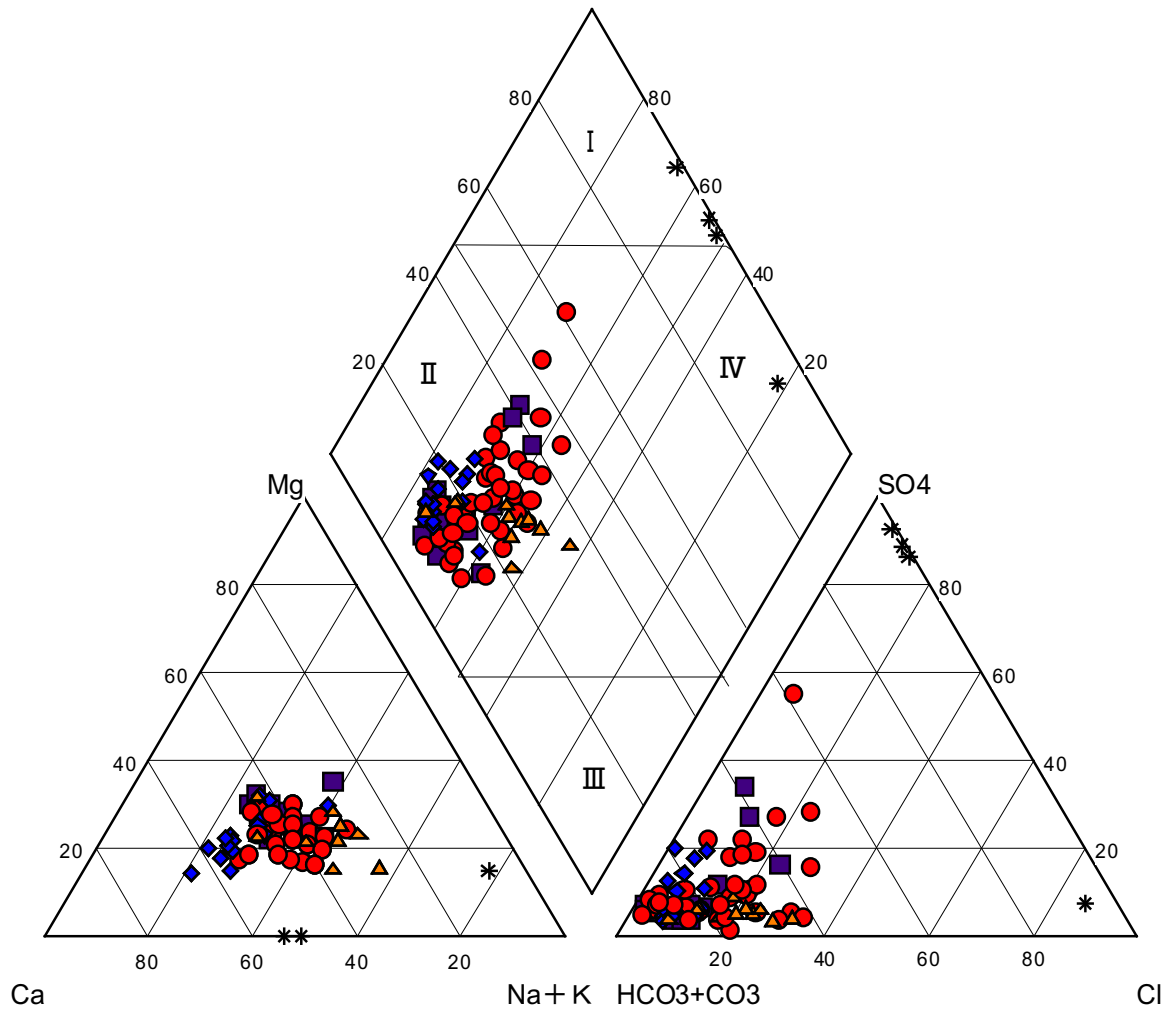


Fig.II-2-3 Piper plot of the surface water chemical composition(Rainy Season)

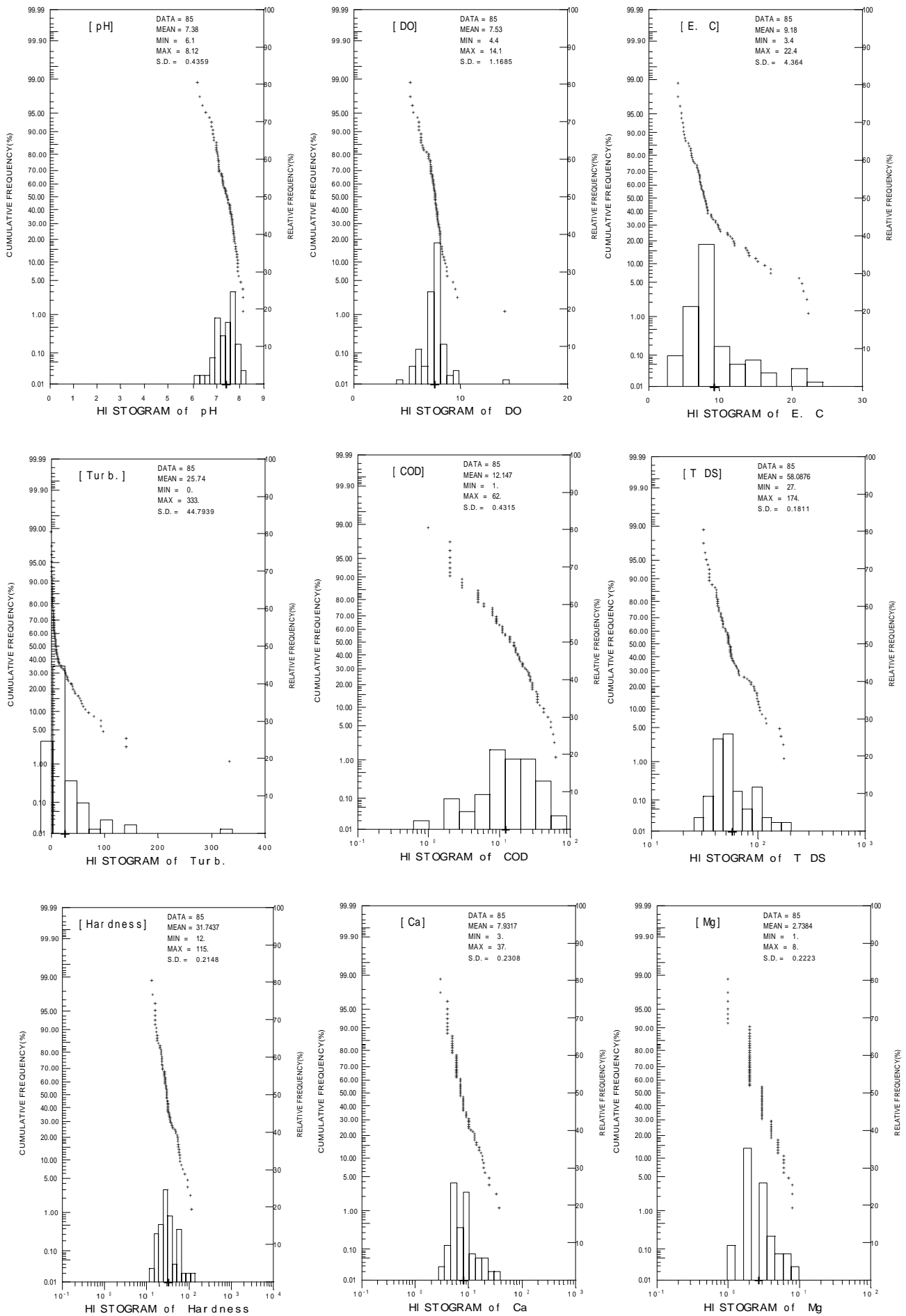


Fig.II-2-4 Probability plot of the surface water samples (Rainy season) (1)

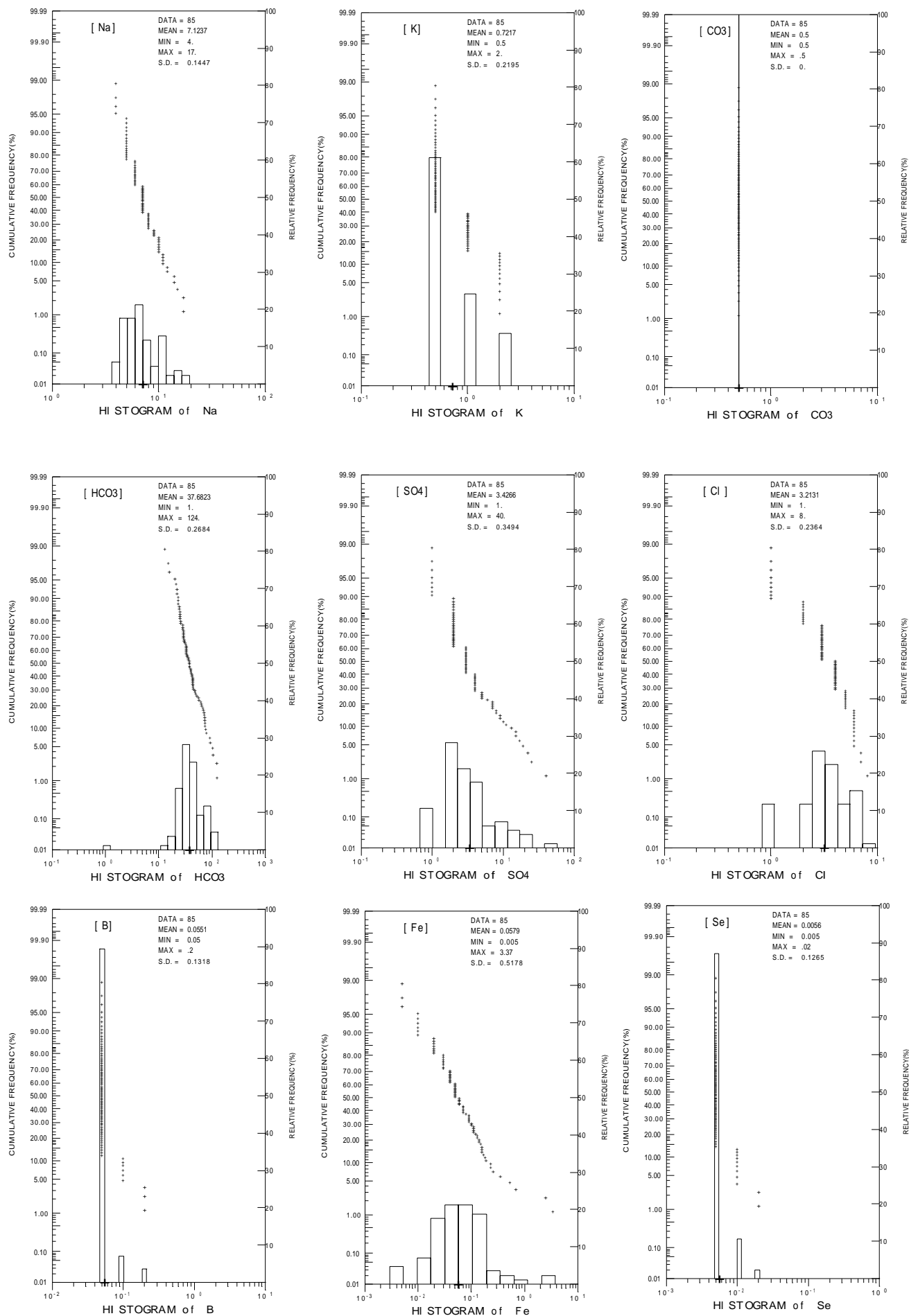


Fig.II-2-4 Probability plot of the surface water samples (Rainy season) (2)

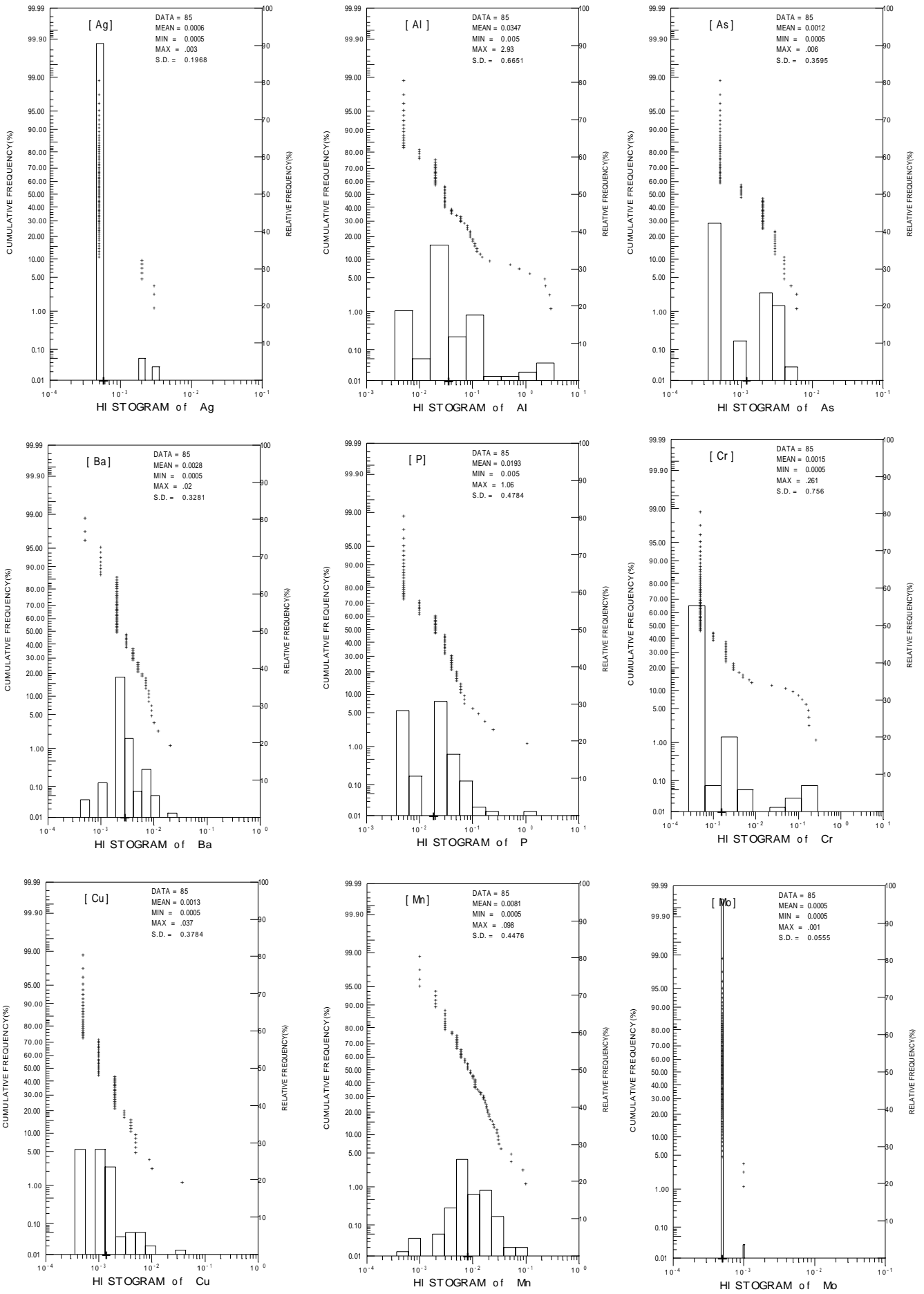


Fig.II-2-4 Probability plot of the surface water samples (Rainy season) (3)

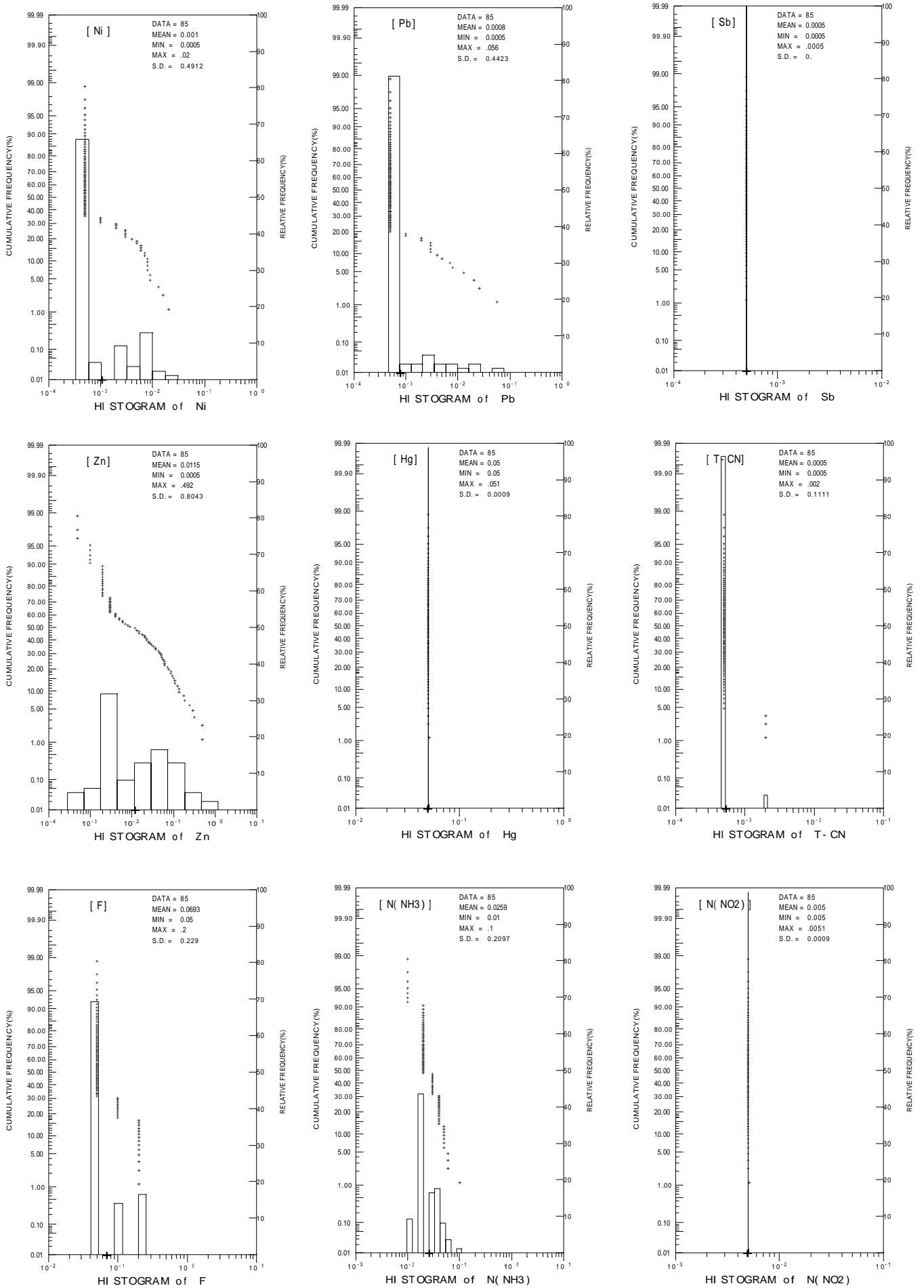


Fig.II-2-4 Probability plot of the surface water samples (Rainy season) (4)