

## A Convenient Multi-parameter Water Quality Analysis by Onsite Filtered Sample for Eutrophication Monitoring

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**ABSTRACT:** Ion Chromatography and Flow Injection Analysis systems were integrated by a switching valve. Then, sampling kit was designed by disposable syringe, 0.45 $\mu$ m syringe filter, and 2mL plastic vial. 13 water samples were collected from oxidation pond and natural stream in a University campus. Four analytical modes were applied for standard solutions and the environmental samples. The detection limit (S/N =3) in  $\mu$ M/L were as follows, SO<sub>4</sub><sup>2-</sup> (0.31), Cl<sup>-</sup> (0.50), NO<sub>3</sub><sup>-</sup> (0.89), Na<sup>+</sup> (0.52), NH<sub>4</sub><sup>+</sup> (0.94), K<sup>+</sup> (1.24), Mg<sup>2+</sup> (0.76), Ca<sup>2+</sup> (1.75), NO<sub>2</sub><sup>-</sup> (0.02), and PO<sub>4</sub><sup>3-</sup> (0.12), and its EC was 0.03  $\mu$ S/cm. Our analytical approach was simple, rapid, low-cost, and multi-parameter that was satisfactory to assess the water samples. Due to the sampling, transportation, storage processes are drastically improved, our approach has potential to contribute to strategic environmental assessment.

**Keywords:** Flow injection analysis, Ion chromatography, Strategic environmental monitoring

### 1. INTRODUCTION

Environmental assessment has multilevel scheme [1][2]. The assessments for environmental acts implementation in the higher planning processes than project level is particularly categorized as strategic environmental assessment (SEA) [1]. Then, the conventional environmental impact assessment (EIA) functions under the SEA at project level [2]. It is clear from the viewpoint of environmental decision-making processes, in the sense, that as one move down the hierarchy from policies, plans, program (PPPs), and then to project, the nature of decision-making has prescribed specifications [2]. There in the water matters, standard methods for water quality analysis [3] have been main technical procedure for EIA under such object specified conditions. On the other hand, even though SEA at higher PPPs process has unique function to enhance more useful problem prospecting and effective environmental programs-projects development [1][2], however the methodologies for suitable water quality monitoring for SEA are still on a development process [4][5]. Hence, technical development for strategic water quality assessment for SEA has been focused on in this study.

Elevated levels of phosphorous in conjunction with nitrogen can negatively affect aquatic ecosystems in many ways in terrestrial fresh water bodies [6][7]. The increased growth of algae and aquatic macrophytes and distinct shifts in species composition are a prominent symptom of eutrophication [8]. These blooms generally contribute to a wide range of water quality problems including summer fish kills, foul odours, and tainted drinking water. Furthermore, certain cyanobacteria produce and release toxins that can kill livestock and may pose serious health threat to humans. To monitor phosphorous and nitrogen concentration of environmental water is important [6][7]. From another view point in general environmental water quality monitoring, the measurement of common anions (SO<sub>4</sub><sup>2-</sup>, Cl<sup>-</sup>, and NO<sub>3</sub><sup>-</sup>) and cations (Na<sup>+</sup>, K<sup>+</sup>, NH<sub>4</sub><sup>+</sup>, Mg<sup>2+</sup>,

and Ca<sup>2+</sup>) found in environmental water is essential for some environmental waters including rain, lake, underground, and river water [9].

Ion Chromatography (IC) has been recognized to be very useful approach for the determination of anions and cations, and Flow Injection Analysis (FIA) is also very fundamental for environmental chemistry. Herein an integration of IC and FIA was examined on analysis for phosphorus, inorganic nitrogen ions, other common anions and cations analysis by only one vial of 2mL onsite filtered sample as a convenient multi-parameter water quality analysis.

### 2. Experimental

#### 2.1 IC-FIA integration

IC-FIA integration was performed on a TOSOH model IC2010 equipped with the following devices: vacuum degasser, double plunger pump that capacity is 6 $\mu$ L x 2, column oven, auto sampler of capacity 150-300 samples, and conductivity detector (TOSOH, Tokyo, Japan). The integration with FIA was proceeded by modification of merging process of double plunger pump by installing a 1-2, 3 switching valve (Fig. 1). Applying 1-2 position of the switching valve, eluent from double plunger pumps were merged before sample injector as conventional IC system. Then, applying 1-3 position of the switching valve, a plunger pump sent carrier and a sample segment was injected in the carrier flowing, and reagent sent by the other plunger pump was merged after the sample injector. Whereas, injected sample and reagent were merged for every 6 $\mu$ L alternately.

#### 2.2 Manifold for IC and FIA analysis

Using, IC mode that was by 1-3 position of switching valve, simultaneous anions and cations separation was carried out using TSK gel Super-IC-A/C (3  $\mu$ m particle size, 0.2 mequiv./ml cationic exchange capacity, 150 x 6.0mm I.D.) with conductivity detector. Using FIA mode that was by 1-2 position of switching valve, two channels FIA manifolds were carried out, in which, 2m SAS tube was applied for reaction at 40 °C for EC analysis, and 5.5m and

4.0m PTFE tube were applied for reaction at 40 °C for  $\text{NO}_3^-$  and  $\text{PO}_4^{3-}$  analysis, with 540nm and 660nm spectrophotometric detector, respectively.

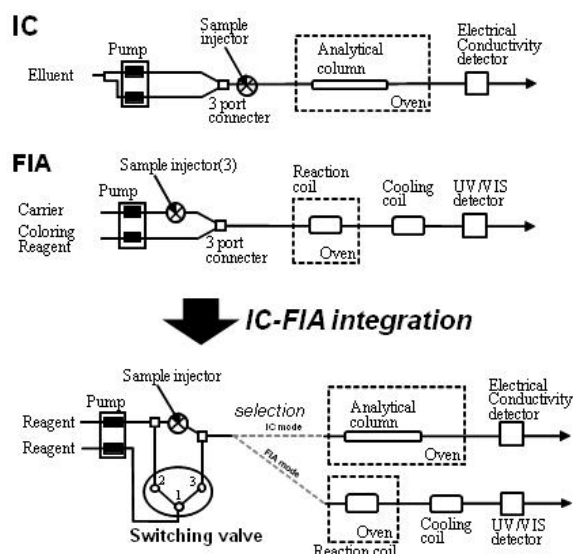


Fig. 1. Schematic depiction of IC and FIA system, and its integration by a switching valve.

### 2.3 Chemicals and analytical conditions

All reagents used in this study were analytical-reagent grade purchased from Sigma Aldrich and Merck, and ultra pure water system (Millipore Direct Q3) was used to prepare standard solutions, washing solvents and eluents. Analytical balance, ATY 224 (Shimadzu, Tokyo, Japan) was used to balance reagents.

**Common Anion and Cation analysis:** A stock solution of  $\text{Na}_2\text{SO}_4$ ,  $\text{KNO}_3$ ,  $\text{NH}_4\text{NO}_3$ , and  $\text{MgSO}_4$ , and a different  $\text{CaCl}_2$  solution were solved to 0.1M/L, respectively. These two stock solutions were mixed with the ultra pure water for calibration purpose for common anions and cations simultaneous analysis. 10m M/L tartaric acid with 3m M/L 18-C-6 was prepared for eluents [10]. Flow rate was 1.0 mL/min, injection volume was 50 $\mu\text{L}$ , and duration of an analysis was 7.5min.

**$\text{NO}_2^-$  analysis:** Stock solution of  $\text{NaNO}_2$  (0.069g) was solved to 50mL ultra pure water as 20mM/L stock solution, and mixed with the ultra pure water for calibration purpose for  $\text{NO}_2^-$  analysis. Concentrated hydrochloric acid (12M/L, 417 $\mu\text{L}$ ) was dissolved to 50mL ultra pure water as 0.1M/L HCl solution. Sulfanil amide (0.5g) was dissolved to 50mL 0.1Mol/L HCl as reagent solution A, and N-(1-Naphthyl)ethylene diamine dihydrochloride (0.05g) was dissolved to 50mL ultra pure water as reagent solution B. The reagent solution A and B are mixed just before analysis as coloring reagent for FIA to analyze  $\text{NO}_2^-$  [11]. Flow rate was 0.25 mL/min x 2, injection volume was 50 $\mu\text{L}$ , and duration of an analysis was 3min.

**$\text{PO}_4^{3-}$  analysis:** Stock solution of  $\text{KH}_2\text{PO}_4$  (0.06804g) was solved to 50ml ultra pure water as 0.01 M/L stock solution, and mixed with the ultra pure water for calibration purpose for  $\text{PO}_4^{3-}$  analysis. Ammonium molybdate (0.274g), antimony potassium tartrate (0.0125g), concentrated sulfuric acid (3.35mL), L-ascorbic acid (1.5g), and sodium

dodecylsulfate (0.05g) were dissolved to 50mL ultra pure water as coloring reagent [12]. Flow rate was 0.5 mL/min x 2, injection volume was 50 $\mu\text{L}$ , and duration of an analysis was 3min.

**EC analysis:** 0.1 mM/L KCl was used for 147 $\mu\text{S}/\text{cm}$  standard solution for EC at 40°C. Flow rate was 1.0 mL/min, injection volume was 50 $\mu\text{L}$ , and duration of an analysis was 3min.

### 2.4 Field sampling (add onsite filtration)

13 environmental water samples were collected into each of 2mL plastic vials by onsite filtration (0.45  $\mu\text{m}$  nylon filter). Sampling locations were where groundwater discharging from a cut slope beside a road (S1), forested upstream (S2-S3) and its downstream of developed campus area (S4-S6), and discharge from the campus (S7), and oxidation pond (S8-S13) that discharge to river between S5 and S6 in UTM Johor campus. These are representing human impacted water environment. The sampling was performed of 12:00 to 13:00 on 24 Feb. 2012.

## 3 RESULTS

Calibration graphs were obtained by plotting peak area against the concentration of standard solutions. Linear calibration graphs ( $r^2 > 0.999$ ) were obtained for anions and cations simultaneous analysis in the concentration range 0-0.8mM for common anions ( $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ , and  $\text{NO}_3^-$ ), 0-0.4mM for cations ( $\text{Na}^+$ ,  $\text{NH}_4^+$ ,  $\text{K}^+$ ,  $\text{Mg}^{2+}$ , and  $\text{Ca}^{2+}$ ), 0.0002-0.025mM for  $\text{NO}_2^-$ , 0.00005-0.05mM for  $\text{PO}_4^{3-}$ , and 0.005-2.0mM (7.35-2940  $\mu\text{S}/\text{cm}$ ) for KCl.

The detection limits determined at a signal-to-noise ratio of three were 0.31  $\mu\text{M}/\text{L}$  for  $\text{SO}_4^{2-}$  (29.5 ppb), 0.50  $\mu\text{M}/\text{L}$  for  $\text{Cl}^-$  (17.7 ppb), 0.89  $\mu\text{M}/\text{L}$  for  $\text{NO}_3^-$  (12.5 ppb), 0.52  $\mu\text{M}/\text{L}$  for  $\text{Na}^+$  (11.9 ppb), 0.94  $\mu\text{M}/\text{L}$  for  $\text{NH}_4^+$  (13.2 ppb), 1.24  $\mu\text{M}/\text{L}$  for  $\text{K}^+$  (48.5 ppb), 0.76  $\mu\text{M}/\text{L}$  for  $\text{Mg}^{2+}$  (18.4 ppb), 1.75  $\mu\text{M}/\text{L}$  for  $\text{Ca}^{2+}$  (70.0 ppb), 0.02  $\mu\text{M}/\text{L}$  for  $\text{NO}_2^-$  (0.7 ppb), 0.12  $\mu\text{M}/\text{L}$  for  $\text{PO}_4^{3-}$  (11.4 ppb), and 0.03  $\mu\text{S}/\text{cm}$  for EC (Table 1).

As shown in Table 1, the water quality of stream water were ranging 4.6-213.4  $\mu\text{M}/\text{L}$  for  $\text{SO}_4^{2-}$ , 68.6-689  $\mu\text{M}/\text{L}$  for  $\text{Cl}^-$ , 3.0-19.0  $\mu\text{M}/\text{L}$  for  $\text{NO}_3^-$ , 79.1-592.8  $\mu\text{M}/\text{L}$  for  $\text{Na}^+$ , 1.2-416.5  $\mu\text{M}/\text{L}$  for  $\text{NH}_4^+$ , 3.8-91.9  $\mu\text{M}/\text{L}$  for  $\text{K}^+$ , 32.9-96.2  $\mu\text{M}/\text{L}$  for  $\text{Mg}^{2+}$ , 61.6-360.4  $\mu\text{M}/\text{L}$  for  $\text{Ca}^{2+}$ , 0.2-2.4  $\mu\text{M}/\text{L}$  for  $\text{NO}_2^-$ , 0.2-22.4  $\mu\text{M}/\text{L}$  for  $\text{PO}_4^{3-}$ , and 292.4-2490.9  $\mu\text{S}/\text{cm}$  for EC (Table 1). Comparing to detection limit shown in Table 1, the resolution among analyte anions, cations, and EC were satisfactory in order to assess the trend of environmental water quality difference in UTM campus (Fig. 2).

## 4 DISCUSSION

In this study, common anions and cations simultaneous analysis for  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ ,  $\text{NO}_3^-$ ,  $\text{Na}^+$ ,  $\text{NH}_4^+$ ,  $\text{K}^+$ ,  $\text{Mg}^{2+}$ , and  $\text{Ca}^{2+}$  were performed by IC mode. Then the analytical resolution was satisfactory and can be considered useful for the accurate determination of these common anions and cations. Moreover, the analysis is a part of an advanced non-suppressor type IC by "polyacrylate- based weakly acidic cation-exchange resin column" with weak-acid eluent [13][14]. By the analytical column, a series of very

Table 1. Water quality of stream water in Univeristy Teknologi Malaysia on 24 Feb. 2012.

	SO <sub>4</sub> <sup>2-</sup>	Cl <sup>-</sup>	NO <sub>3</sub> <sup>-</sup>	Na <sup>+</sup>	NH <sub>4</sub> <sup>+</sup>	K <sup>+</sup>	Mg <sup>2+</sup>	Ca <sup>2+</sup>	NO <sub>2</sub> <sup>-</sup>	PO <sub>4</sub> <sup>3-</sup>	EC
	[ $\mu$ M/L]	[ $\mu$ M/L]	[ $\mu$ M/L]	[ $\mu$ M/L]	[ $\mu$ M/L]	[ $\mu$ M/L]	[ $\mu$ M/L]	[ $\mu$ M/L]	[ $\mu$ M/L]	[ $\mu$ M/L]	[ $\mu$ S/cm]
S1 Groundwater discharging from cut slope	14.7	124.1	18.8	111.9	3.6	3.8	45.3	61.6	2.4	0.190	344.9
S2 Natural stream in forested area	4.6	68.6	6.3	79.1	2.6	5.7	52.5	72.5	0.2	0.174	292.4
S3 Nagural stream after small human effect	15.3	93.5	15.4	105.8	2.7	8.5	45.4	79.4	0.8	0.183	358.2
S4 Up stream, open water	14.1	77.4	8.8	93.7	2.6	7.5	96.2	165.6	0.2	0.207	554.1
S5 River, upstream of oxidation pond	36.9	109.5	3.0	130.2	1.2	17.8	33.6	200.7	0.2	0.168	594.6
S6 Downstream of oxidation pond	108.5	287.9	9.9	259.0	119.3	43.5	36.3	292.1	0.9	0.280	1166.6
S7 River, infront of security gate	110.2	311.0	19.0	263.3	111.8	50.4	37.3	294.4	1.6	0.620	1206.0
S8 Oxidation pond (NE)	160.4	404.3	9.2	318.0	143.4	58.5	40.0	315.9	2.0	0.348	1451.8
S9 Discharge from oxidation pond	157.2	428.8	11.5	352.5	235.9	61.4	37.6	327.9	0.9	0.504	1641.2
S10 Oxidation pond (NW)	155.3	454.1	6.4	371.3	227.0	65.7	34.9	314.1	0.5	0.541	1610.5
S11 Oxidation pond (SE)	167.0	481.9	6.8	379.7	255.6	70.1	32.9	315.5	0.2	0.696	1720.7
S12 Oxidation pond (SW)	174.6	517.1	7.9	404.6	360.5	78.4	37.8	352.9	0.2	7.340	2022.1
S13 Inflow water to oxidation pond	213.4	689.0	12.9	592.8	416.5	91.9	40.6	360.4	1.7	22.364	2490.9
Environmental sample data ( <i>max</i> )	213.4	689.0	19.0	592.8	416.5	91.9	96.2	360.4	2.4	22.4	2490.9
Environmental sample data ( <i>min</i> )	4.6	68.6	3.0	79.1	1.2	3.8	32.9	61.6	0.2	0.2	292.4
Caribration graph range ( <i>max</i> )	400	400	400	400	400	400	400	400	25	50	2940
Caribration graph range ( <i>min</i> )	0	0	0	0	0	0	0	0	0.2	0.05	7.4
Detection Limit*	0.31	0.5	0.89	0.52	0.94	1.24	0.76	1.75	0.02	0.12	0.03

\*: The detection limits determined at a signal-to-noise ratio of three.

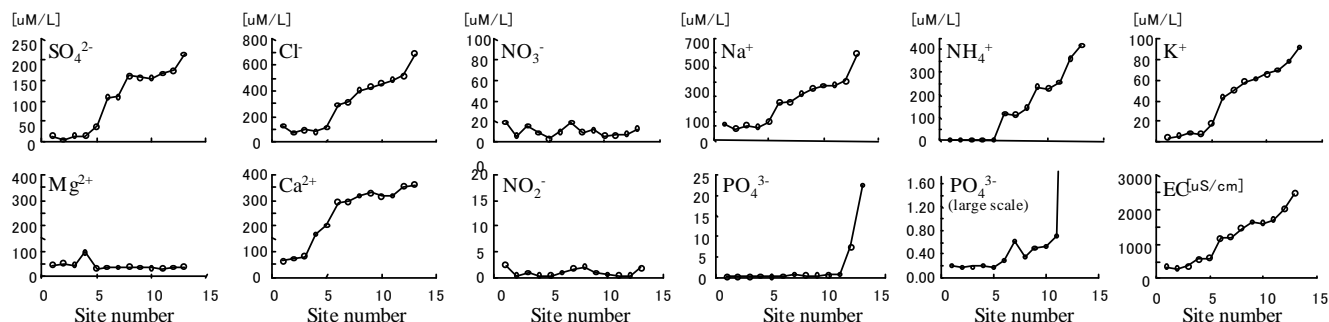


Fig. 2 Water quality of stream water in Universiti Teknologi Malaysia on 24 Feb. 2012. Comparing to detection limit shown in table 1, the resolution among analyte anions, cations, and EC were quite satisfactory, and the methods were useful for the accurate determination of these parameters in common river water.

functional water quality analysis are obtained, such as, these 8 ions plus PO<sub>4</sub><sup>3-</sup> and SiO<sub>4</sub><sup>2-</sup> simultaneous analysis[15], HCO<sub>3</sub><sup>-</sup> analysis[16], simultaneous heavy metal analysis for Ni<sup>2+</sup>, Zn<sup>2+</sup>, Co<sup>2+</sup>, Mn<sup>2+</sup>, and Cd<sup>2+</sup> [17]. Applying this advanced IC, there is a potential to develop integrated IC for common cation and anion, nutrients, and heavy metals by only one analytical column and equipment.

However, some important parameters, for example COD, total nitrogen (TN), total phosphorous (TP) are impossible to analyze by conventional IC, and generally seawater samples are not applicable for IC. In addition, some parameters are not applicable for IC. For example IC for phosphorous has low sensitivity for environmental monitoring [15]. On the contrary, FIA has advantage for these analyses [11][12][18][19]. Accordingly, because of similarity for system design between IC and FIA, these analytical systems were integrated in this study (Fig. 1). Consequently, SO<sub>4</sub><sup>2-</sup>, Cl<sup>-</sup>, NO<sub>3</sub><sup>-</sup>, Na<sup>+</sup>, NH<sub>4</sub><sup>+</sup>, K<sup>+</sup>, Mg<sup>2+</sup>, Ca<sup>2+</sup>, NO<sub>2</sub><sup>-</sup>, PO<sub>4</sub><sup>3-</sup>, and EC were able to be analyzed from only 2mL onsite filtered sample in a plastic vial. This multi-parameter analysis can be extended to TP [12], TN [18], COD [19], HCO<sub>3</sub><sup>-</sup> [16] within another one 2mL vial sample, easily, and the analytical capacity is several hundred samples regarding the capacity of auto sampler of IC2010.

In order to embark on effective environmental restoration programs and projects, SEA is quite important [1], where new methodologies for SEA need to be developed [8][9]. According to literature [8][9], expected properties of such new approach is "rapid delivery of results, on-site, low-cost, and capacity to acquire large number of observations within a short time frame". Regarding the requirement, the concept of on-site analysis was eliminated, and time frame for rapid delivery of result

is assumed as one day, and then, convenient experiment procedure, satisfactory accuracy, capacity of automated large number sample analysis, and integrated multi-parameter analysis were of more concern in this study. According to our analytical approach, because of reduction of sample volume, even concept of onsite analysis was eliminated, field sampling process and sample transportation process were drastically improved, and then, convenient and enough accuracy of multi-parameter large number sample was available, which will contribute to SEA as a new technical approach that improves problem recognition processes in environmental prospective and profiling.

In water environmental management, the communication gap (CG) between water authorities and public causes difficult chronic management problem in water-environment monitoring and assessment [5]. The potential solution is to prepare useful information, where our multi-parameter convenient approach will contribute to give new approach to solve the CG by rapid delivery of data, low-cost, and high capacity to acquire large number of observations of integrated data.

## 5. CONCLUSION

Ion Chromatography and Flow Injection Analysis integration was performed, which was satisfactory to analyze SO<sub>4</sub><sup>2-</sup>, Cl<sup>-</sup>, NO<sub>3</sub><sup>-</sup>, Na<sup>+</sup>, NH<sub>4</sub><sup>+</sup>, K<sup>+</sup>, Mg<sup>2+</sup>, Ca<sup>2+</sup>, NO<sub>2</sub><sup>-</sup>, and PO<sub>4</sub><sup>3-</sup> in  $\mu$ M/L level, and EC in  $\mu$ S/cm by only one equipment within 2mL onsite filtered sample. The analysis can be extended to COD, TP, and TN. A convenient water quality prospecting was available for strategic environmental monitoring due to rapid delivered, low-cost, and integrated data.

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