ORIGINAL ARTICLE

Surrogate parameters for rapid monitoring of contaminant removal for activated sludge treatment plants for para rubber and seafood industries in Southern Thailand

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Abstract

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This study aimed at using surrogate parameters for rapid monitoring of contaminant removed of activated sludge treatment plant for para rubber and seafood industries in Southern Thailand. Wastewaters from these industries contain high organic concentrations and chemicals. The activated sludge process (AS) is usually applied as a treatment process. However, plant operators generally lack the understanding and means to control the treatment plants because of a continuous monitoring system is not employed and the monitoring parameters are time consuming. UV absorbency at various wavelengths was used in this study as a surrogate parameters, for predicting the removal capacity of each plant. COD, BOD, suspended solids and nitrate-nitrogen concentrations could be estimated reliably without being time consuming. The results showed that UV absorbency at 220 nm can be used as a parameter to predict nitrate-nitrogen concentrations which less than 15 mg/L. That at 550 nm is for predicting suspended solids concentration and that at 260 nm is for COD predict.

Key word : activated sludge process, industrial wastewater, surrogate parameter

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บทคัดย่อ

พนาลี ชีวกิดาการ

พารามิเตอร์อย่างง่ายสำหรับการตรวจวัดการกำจัดสารปนเปื้อนในโรงบำบัดแบบตะกอนเร่งของโรงงานน้ำยางข้นและโรงงานอาหารทะเลในพื้นที่ภาคใต้ของประเทศไทย

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การศึกษาในครั้งนี้เพื่อพิจารณาการเลือกใช้พารามิเตอร์อย่างง่ายในการตรวจสอบการบำบัดน้ำเสียของระบบบำบัดนำเสียแบบตะกอนเร่งจากโรงงานยางพาราและอาหารทะเล ซึ่งน้ำเสียจากโรงงานเหล่านี้ มีความเข้มข้นของสารอินทรีย์และสารเคมีอื่น ๆ สูงมาก ดังนั้นโรงงานเหล่านี้จึงเลือกที่จะใช้ระบบบำบัดน้ำเสียแบบตะกอนเร่ง แต่อย่างไรก็ตามผู้ควบคุมระบบบำบัดยังขาดความเข้าใจและยังไม่สามารถที่จะควบคุมระบบบำบัดแบบตะกอนเร่งได้อย่างมีประสิทธิภาพเท่าที่ควร เนื่องจากขาดแคลนข้อมูลและความสามารถในการติดตามระบบอย่างใกล้ชิดและทันท่วงที ค่าการดูดซับแสงยูวีที่ความยาวคลื่นต่าง ๆ กันทำหน้าที่เสมือนพารามิเตอร์อย่างง่ายในการทำนายประสิทธิภาพการบำบัดน้ำเสียของแต่ละโรงบำบัด ค่าความเข้มข้นของบีโอดี ค่าซีโอดี สารแขวนลอย และไนเตรตไนโตรเจน สามารถที่จะถูกประมาณค่าได้อย่างรวดเร็ว และมีความเชื่อถือได้ ด้วยการใช้ค่าดูดซับแสงดังกล่าว จากผลการทดลองพบว่าค่าการดูดซับแสงที่ความยาวคลื่น 220 นาโนเมตร สามารถทำนายค่าความเข้มข้นของไนเตรต-ไนโตรเจนที่มีความเข้มข้นน้อยกว่า 15 มก./ล. และที่ความยาวคลื่น 550 นาโนเมตร สามารถทำนายค่าความเข้มข้นของสารแขวนลอย สำหรับที่ความยาวคลื่น 260 นาโนเมตร สามารถทำนายค่าความเข้มข้นของซีโอดีได้

คณะการจัดการสิ่งแวดล้อม มหาวิทยาลัยสงขลานครินทร์ อำเภอหาดใหญ่ จังหวัดสงขลา 90112

Activated Sludge (AS) process is one of the most efficient biological processes currently used for effluent treatment. It is very flexible and can be adapted to almost any type of biological wastes. In Southern Thailand industry is based mainly on para rubber and seafood processing. The wastewaters from such factories contain high organic carbon and nutrient levels, and have special characteristics containing specific chemicals. AS is frequently applied to treat effluent from these factories in order to increase their treatability using a limited land area for treatment plant. However, little information on the process is available to the operators as a result of a lack of continuous monitoring.

It appears that carbon and solids removal (measured as COD, BOD_5 and suspended solids) are the major concern of plant operators. However, COD and BOD_5 are aggregate parameters which only provide limited qualitative information and require the use of time consuming and complicated chemical analytical techniques. Plant operators who need to control the process removal capacity require fast and simple methods in order to achieve optimal treatment. For these reasons UV absorption has long been used as a surrogate parameter to estimate organic carbon content in the water treatment field. This technique is quick and inexpensive and allows rapid monitoring of the removal efficiency of wastewater and water treatment.

Tambo and Kamei (1978) used UV absorbance at 260 and TOC to evaluate the treatability of the organic material by biological treatment plants. James *et al*. (1985) suggested UV absorbance at 254 nm as an excellent surrogate parameter for estimating the raw water concentrations of organic carbon and THM precursors. Jun (1995) combined the uses of UV absorbances at 220, 260 and 500 nm as a tool to monitor jar test performance, and confirmed his idea by monitoring a full-scale water treatment plant.

However, no experiments on UV absorption have been conducted under conditions of high BOD concentration. It is well known that wastewater concentrations from the para rubber and seafood industries are very strong. Not only are organic concentrations in terms of BOD_5 and COD very high, but also to are nutrients and sulfate concentrations. There is doubt whether the correlation between conventional measures and UV absorption still holds under these conditions.

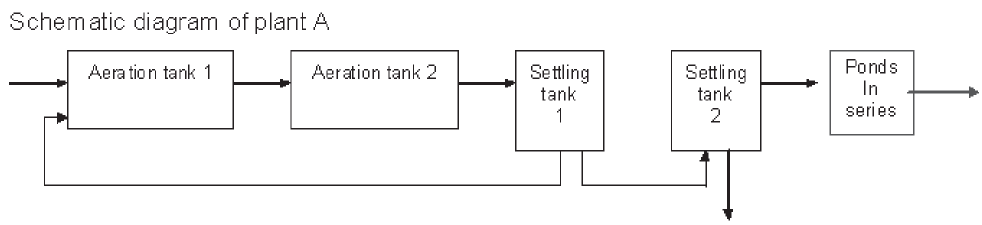
The main objective of this study was therefore to investigate the relationship between conventional analytical parameters and surrogate parameters for treatment of wastewater from the para rubber and seafood industries, not only to reduce the cost of chemical analysis but also to create an innovative option to allow plant operators to control the capacity of their treatment plants.

Methodology

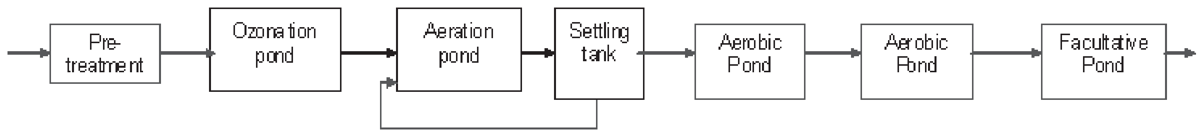
Wastewater samples were collected from four treatment facilities representing both para rubber (Plants A and B) and seafood industries (Plants C and D) in Songkla, Thailand, over the period May 2003 - January 2004 (once per month for each plant). All treatment plants used activated sludge processes with various modifications. Figure 1 shows the schematic diagram of each plant.

Plant A is from the latex industry. Its wastewater concentration is very strong and contains a high concentration of sulfate. The treatment plant starts with two aeration tanks, two settling tanks

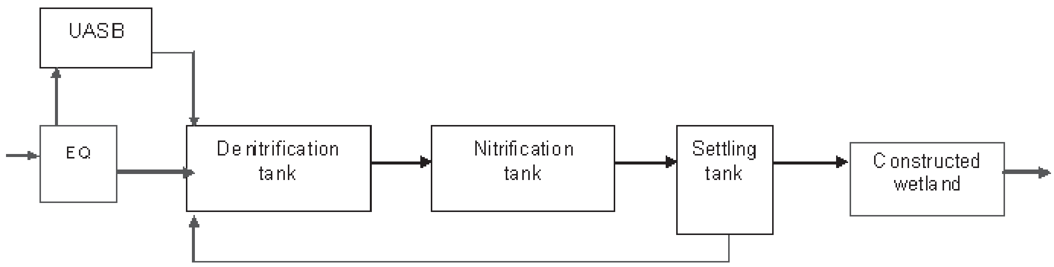
Schematic diagram of plant A



Schematic diagram of plant B



Schematic diagram of plant C



Schematic diagram of plant D

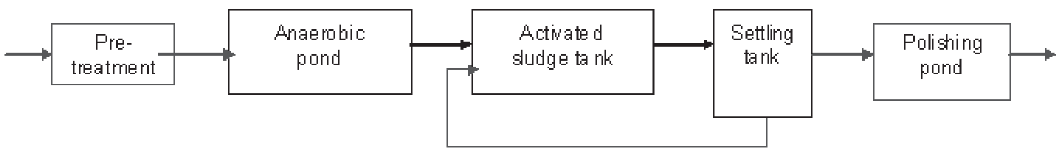


Figure 1. Schematic diagram of plants A, B, C and D

and ponds, after the settling tanks, in series. Plant capacity is currently 3,500-5,000 kg BOD_5/d. Plant B is also from the latex industry. The treatment plant consists of aeration tanks, a very small settling tank and ponds in series, after the aeration tanks. Plant capacity is currently 750-1,000 kg BOD_5/d.

Plant C is from the frozen seafood industry (shrimp processing). Its wastewater concentration has a high concentration of nitrogen. The treatment plant is a complete ASP designed for both carbon and nitrogen removal. The facility consists of a nitrification tank, a denitrification tank and a settling tank. Plant capacity is currently 1,000-1,400 kg BOD_5/d. Plant D is also from the frozen seafood industry (fish processing). Its wastewater contains a high concentration of carbon and grease. The treatment plant consists of an aeration pond and a settling tank and anaerobic pond as pre-treatment. Plant capacity is currently 1,000-2,000 kg BOD_5/d.

In each of the four plants, the AS is equipped with other pre- and post-treatment units, such as upflow anaerobic sludge blanket (UASB), ponds, or wetland. Because of the high concentrations of influent, AS process alone is unlikely to be a single solution able on its own to reduce contaminant levels.

Wastewater characteristics from influents and effluents of the whole treatment processes, and mixed liquor were analyzed by both laboratory and onsite measurements. All chemical tests in laboratory were performed according to Standard Methods for the Examination of Water and Wastewater (APHA, 1998) BOD_5 and COD analysis was undertaken for both filtered and non-filtered samples.

A Shimadzu UV 1601 spectrophotometer was used to measure the absorbance of unsaturated organics at wavelengths of 220, 254, 260, and 550 nm (E220, E254, E260, and E550) in a 1 cm quartz cuvette cell. To avoid interference from particulate material in wastewater samples, samples were filtered through a 0.45 µm pore size cellulose nitrate filter membrane (Sartorious AG.) to remove all suspended solids.

Results and Discussion

Treatability Evaluation: In this study, the total removal efficiencies of BOD_5, COD, total nitrogen and total suspended solids are defined by the following equation.

$$R = \frac{(\text{Influent concentration} - \text{Effluent concentration})}{\text{Influent concentration}} \times 100$$

Where R = Total removal efficiency. Table 1 presents the total removal efficiencies of each treatment plant for the several parameters investigated.

As the AS of these plants A, B and D are conventionally designed for carbon removal whereas plant C has tertiary treatment for nitrogen removal. The removal of BOD_5 and COD was between from 96 and 99 percent (see Table 1). Nitrogen removal of plant C was higher than those in plants A, B and D. However, without nitrogen removal units the total nitrogen removal in these plants was higher than 50 percent. This might possibly be the result of unexpected simultaneous nitrification-denitrification processes occurring in

Table 1. Average removal efficiencies, calculated from non-filtered samples for each treatment plant with their standard deviations.

Removal efficiency	Plant A	Plant B	Plant C	Plant D
BOD_5	99.53±0.22	99.53±0.19	99.77±0.08	99.45±0.39
COD	98.52±0.42	98.60±0.51	97.85±1.11	96.73±1.05
SS	87.15±7.08	78.05±4.85	93.63±3.53	93.89±7.60
Total nitrogen	69.02±48.88	54.00±19.25	83.64±6.32	64.66±24.11

(All units are in percent)

the aeration tanks at these plants.

Using surrogate parameters to estimate suspended solids (SS)

It is well known that E550 can show a good correlation with suspended solids. In this study, samples of influent, and effluent from biological treatment processes were selected for which suspended solids (SS) measurements using the standard method ranged from 3 to 2,375 mg/L. E550 was measured for these samples and Figure 2 shows the results of the experiments for both seafood and para rubber industries. The results show a close relationship between E550 and suspended solids when segregated into influent and effluent from biological processes.

It can be concluded that E550 may be used as a surrogate parameter for estimating suspended solids concentrations. Filtration of wastewater through a membrane filter is not required for this method. In only a few minutes the SS concentration can be derived at a low cost.

Using surrogate parameters to estimate nitrate-nitrogen

Wang and Hsieh (2001) concluded that the presence of NO_3-N in water causes major interference with absorbance measured at low wavelengths (< 250 nm). Therefore in this stage of the study the correlation between E220 and NO_3-N was investigated. The results are presented in Figure 3.

The result shows a close correlation between NO_3-N and E220. However, the correlation equations, which are shown in Figure 3, can be used for estimation only when the nitrate-nitrogen concentration is less than 15.0 mg/L. At concentrations higher than 15.0 mg/L, the E220 will be higher than the detection limit of the spectrophotometer.

Using surrogate parameters to estimate COD and BOD_5

No correlation was found for the full COD and BOD_5 data set, for non-filtered samples. Data were separated into two groups for further analysis: one from samples obtained from the influent into wastewater treatment facilities and the other from samples obtained from effluent flows from biological treatment processes. Only filtered BOD_5 and COD ($FBOD_5$ and FCOD) were analyzed. Samples were also separated between seafood and

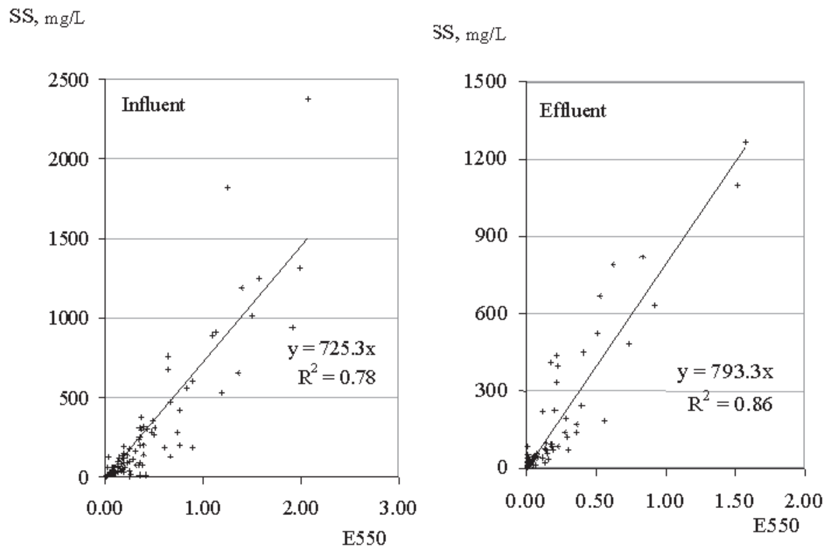


Figure 2. Correlations between SS and E550 for both industries, segregated into influent and effluent from biological treatment processes.

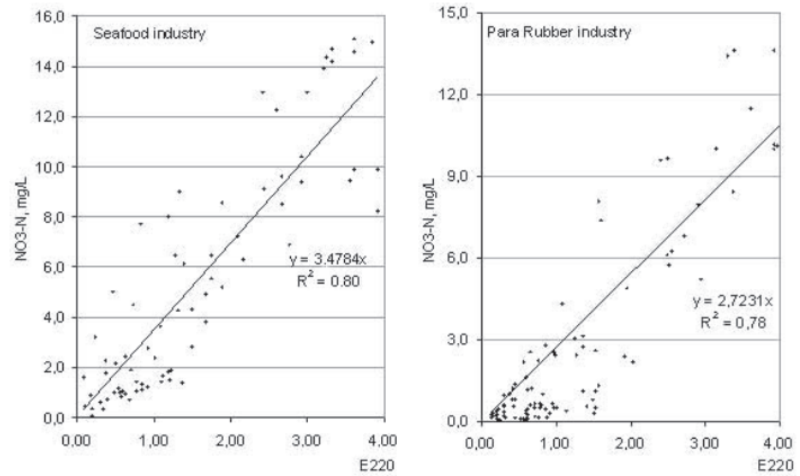


Figure 3. Correlations between NO_3-N and E220 for the para rubber industry at NO_3-N levels less than 15.0 mg/L.

para rubber wastewaters as each kind of wastewater contains different groups of organic materials.

Figures 4 and 5 show a close relationship between lumped organic parameters (FCOD) and E260 for each kind of industry. In summary, FCOD gave a better correlation with E260 than $FBOD_5$. Both gave good correlation coefficients (R) ranging from 0.89 to 0.96. For UV absorbance at 254 nm, E254, coefficients were less than those from E260 and so E260 was therefore selected as a surrogate parameter for prediction of FCOD.

For the estimation of $FBOD_5$, the relationship between BOD_5, FCOD and E260 was investigated. Ping (1996) reported that $FBOD_5$ could be estimated by using FCOD/E260. Her work showed a reliable correlation between $FBOD_5$ and FCOD/E260.

In contrast to this study, Ping's work was

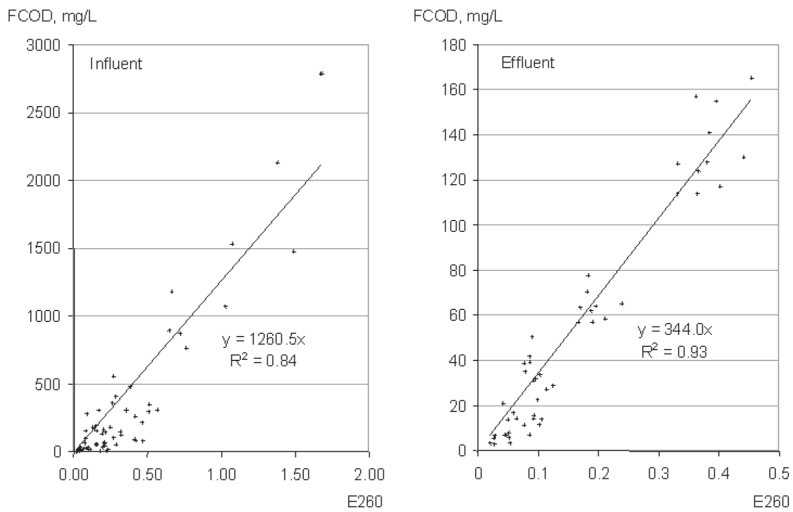


Figure 4. Correlations between FCOD and E260 for the seafood industry, segregated into influent and effluent from biological treatment processes.

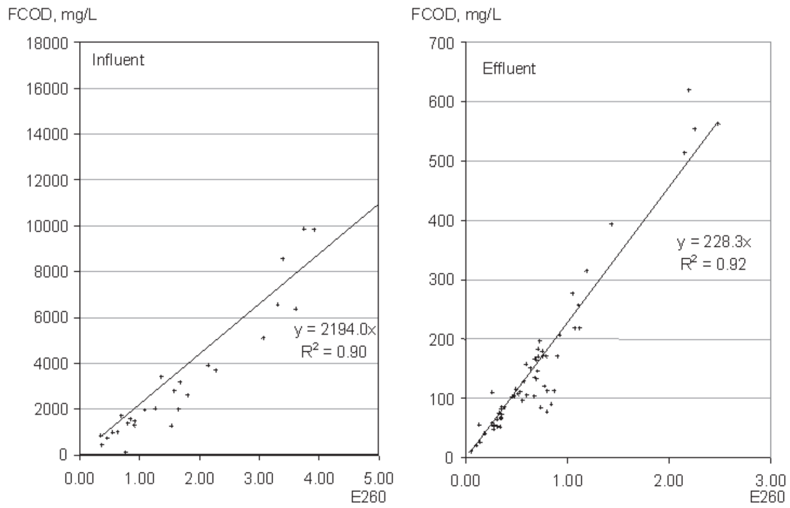


Figure 5. Correlations between FCOD and E260 for the para rubber industry, segregated into influent and effluent from biological treatment processes.

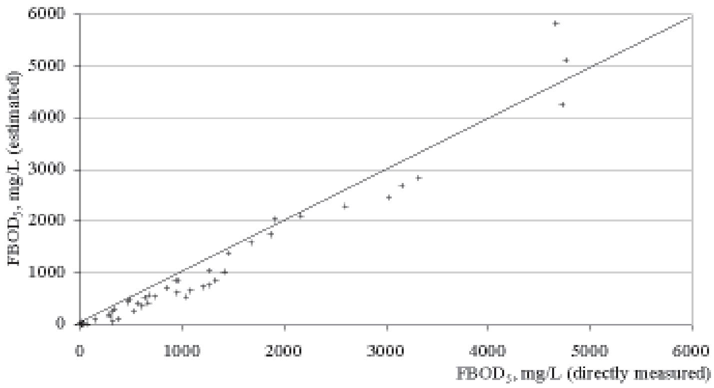


Figure 6. Comparison of assay results for filtered BOD_5 analyzed using standard methods and with the UV analyzer (para rubber industry samples)

based on samples from the Chao Praya river water which demonstrated $FBOD_5$ in the range of 0-30 mg/L. Wastewater concentrations from the para rubber and seafood industries examined in the study varied. The range of filtered BOD_5 values obtained using the standard method (direct measurement) was 0.3-4,762 mg/L. The range of values measured using UV absorbance (estimate) was 0.4-5,822 mg/L.

Figures 6 and 7 show the relationship between directly measured and estimated values from the para rubber and seafood industries respectively.

In general, the error (difference between directly measured and estimated values) ranged from ±0.1 to ±560.0 mg/L. Wastewater from the para rubber industry, separated into effluent BOD_5 and influent BOD_5, showed average errors of ±3.3 and ±255 mg/L respectively. Wastewater from the seafood industry had average errors of ±8.1 and ±32.4 mg/L. It can be seen that the higher BOD_5 was, the higher was the error.

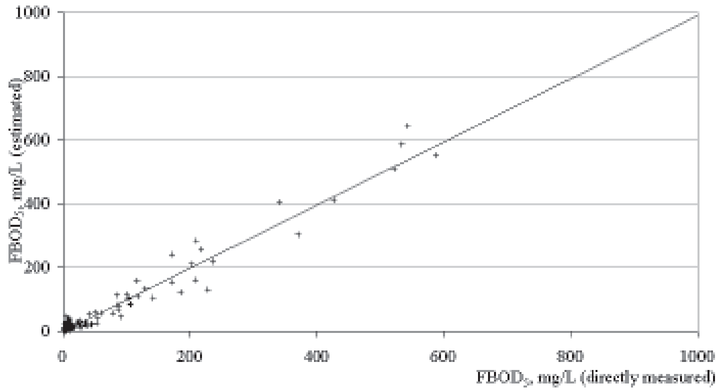


Figure 7. Comparison of assay results for filtered BOD_5 analyzed using standard methods and with the UV analyzer (seafood industry samples)

Conclusion

The following conclusions can be drawn:

1. E260 can be used as a simple surrogate wastewater quality parameter in the same way as it can also be used as a surrogate parameter for water samples. However, the correlation between E260 and quality parameters differs for each type of wastewater.

2. Correlation coefficients for E260 with COD for industrial wastewaters are more reliable than those for E260 with BOD_5, when using E260 alone. To increase reliability, BOD_5 should be estimated by using both COD and E260 correlations.

3. E220 can be used as a parameter to predict nitrate-nitrogen concentration. However, it may be used only when the nitrate-nitrogen concentration is less than 15 mg/L.

4. E550 can be used as a rapid surrogate parameter for predicting suspended solids concentration.

Acknowledgement

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References

APHA. 1998. Standard Methods for the Examination of Water and Wastewater, 20th ed. American Public Health Association, Washington, DC.

James, K.E., William, C.B., and Kevin, L.W. 1985 Surrogate parameters for monitoring organic matter and THM precursors. J. AWWA. 77(4), 122-132

Jun, H. 1995. Water quality evaluation by simple and rapid surrogate water quality parameters. Master thesis, School of Environmental, Resources and Development, Asian institute of Technology, Bangkok Thailand

Ping, L. 1996. Development of simple surrogate water quality parameters for rapid assessment. Master thesis, School of Environmental, Resources and Development, Asian institute of Technology, Bangkok Thailand

Tambo, N. and Kamei, T. 1978. Treatability evaluation of general organic matter matrix conception and its application for a regional water and wastewater system. Wat. Res. 12, 931-950

Wang, G.S. and Hsieh, S.T. 2001 Monitoring natural organic matter in water with scanning spectrophotometer. Env. Int. 26(2001), 205-212