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13th IWA Specialized Conference on
Watershed and River Basin Management, September 9th-12th, 2014,
San Francisco, USA

Acceptance letter

Dear Dr. Zaki Zainudin,

Congratulations! After a peer-review of your submission "*E. Coli In Tropical Urban Rivers: A Case Study Of The Sungai Gombak Basin"* your abstract has been ACCEPTED for an oral presentation in the technical programme of the 13th IWA Specialized Conference on Watershed and River Basin Management. **To finalize your inclusion in the conference program you must be fully registered, including final payment, no later than May 31st, 2014.**

Contributed oral presentations are allotted 15 minutes plus 5 minutes for questions, and will be placed in thematic sessions scheduled Wednesday morning to Thursday afternoon. By submitting an abstract, it is expected that authors will be available during any of these time slots. You will be notified of you final presentation time in July.

The goal of the Watershed and River Basin Management (WRBM) Specialist Group is to promote the understanding, utilization, and values of integrated watershed management approaches for the beneficial and sustainable use of rivers and watersheds worldwide. It seeks to achieve this by sharing of expertise and experience among its members and with other interested individuals and organizations

Experts from around the world will come together this September in San Francisco, California, USA to network, explore, and discuss cutting edge issues related to sustainable watershed management, with a special focus on emerging issues related to the impacts of climate change on watershed management. Conference topics will include impacts of climate change on watershed management, water energy nexus, managing watersheds across political boundaries, flood control, harmful algae blooms, new tools and technologies in watershed management, irrigated agriculture, and more.

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Abstract editing is now available and can be accessed through **Friday June 13th, 2014**. To review and make changes your abstract, please read and follow the following instructions carefully.

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Attention students! This is your only opportunity to edit your co-author list. Please make sure important names (i.e. your advisor) appear as they should in the program! We will be unable to edit co-authors after the editing period has ended.

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Full Paper Submissions
The deadline for full paper submissions is **June 30th, 2014**. Submission of a full paper is optional. Instructions for full papers to be included in conference proceedings can be found here. Selected papers will be peer reviewed for publication in IWA Publishing's journals *Water Science and Technology*, *Water Science and Technology: Water Supply*, or *Water Practice and Technology*.

Conference Registration
The following link will take you to the conference registration site:
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All presenters are expected to register and pay in full no later than May 31st.

Cancellation Policy
Early Registration rates apply through May 31st, 2014. May 31st, 2014 is the deadline to receive a full refund. Should you decide not to attend the conference after May 31st, 2014 you will only receive a 50% refund of your conference fee. After July 15th, no refunds will be issued.

Hotel Reservations
Be sure to book your hotel stay at the beautiful JW Marriott in San Francisco where you will receive discounted conference pricing. If you will be staying at the hotel before or after the conference we encourage you to do so. The hotel will honour the discounted conference room rate between Friday September 5th and Monday September 15th, 2014. If you would like a room with two double beds instead of 1 king bed, you may need to contact the hotel directly at +1 415-771-8600 to make your reservation. Be sure to mention that you are with the IWA conference when calling to receive the discounted rate.

Further information can be found on the conference webpage (http://www.iwa2014sanfrancisco.org/) or you can contact Chelsea Spier (conference organizer) at iwa2014wrbm@gmail.com for more information on the aforementioned conference.

I look forward to welcoming you in San Francisco in September!

Kind regards,
On behalf of the conference program committee

William T. Stringfellow
Conference Chair

E. coli in tropical urban rivers : A case study of the Sungai Gombak basin

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Abstract
The primary study area is Sg. Gombak, a river that flows through the mostly urbanized state of Selangor and transcends the capital of Malaysia, Kuala Lumpur. The study aims to characterize *E. coli*, organics and nutrients on the main stem of the river and its tributaries of Sg. Batu and Sg. Kerayong. There were 28 identified spatial sampling stations throughout the basin. The results on the upper reaches of Sg. Gombak showed *E. coli* levels ranged between 100 – 400 cfu/100mL. The levels increased and remained between 11,000 cfu/100mL to 18,000 cfu/100 mL downstream upon receiving sewage effluent and other pollution sources. This was comparable to Sg. Batu. Conditions were even worse in Sg. Kerayong as *E. coli* levels were in excess of 140,000 cfu/100 mL. Ambient temperature increase in excess of 30°C with a ΔT rise of 3 to 4°C appeared to result in some decrement of *E. coli*; at 0.08/°C for Sg. Gombak and 0.20/°C for Sg. Batu, albeit this only occurred at single spatial points in both rivers. Variation in BOD_5, NH_3-N and NO_3-N did not appear to significantly influence bacterial count in the basin. The study results also showed for the water to be deemed suitable for skin contact, a removal efficiency of at least 92% has to be achieved, which in turn, translated to a die-off period of at least two hours.

Keywords
E. coli, Kuala Lumpur, Sungai Klang, Sungai Gombak

INTRODUCTION

The main study area is the Sg. Gombak, an urban river, which flows through the Klang Valley. The main-stem and tributaries also flow through satellite towns such as Petaling Jaya, Subang Jaya, Shah Alam and Klang. These flows culminate into Sg. Klang in the downstream reaches. The river receives a myriad of pollution load from domestic and industrial sources and has a reputation as being one of the most polluted rivers in the Malaysia (Zainudin et al., 2013; Abdullah. 2013).

Water quality benchmarking in Malaysia is usually done via the Department of Environment - Water Quality Index (DOE-WQI). The index consists of six aggregated parameters (sub-indices) of; dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen (NH_3-N), pH and suspended solids (SS). It gives an indication of the water quality status of most rivers in Malaysia.

Information on the DOE-WQI is in the public domain (DOE, 2012), unlike bacterium data, which is not so readily available even though monitored by the authorities. The matter becomes more of concern when bacterium, which typically originates from sewage sources, is not controlled under prevailing sewage effluent discharge regulations (DOE, 2009). What this implies is; there is no requirement or compulsion on the part of sewage operators to incorporate disinfection as part of the treatment process (Ujang and Henze, 2006).

The consequence of which was fully experienced in the February 2014 *E. coli* crisis in Penang, a northern state of Malaysia. The in-stream *E. coli* count in Sungai Batu Feringghi (Batu Feringgi river) was reported to have reached 16,000 cfu/100 mL (Saad, 2014). The river empties into the coastline adjacent to a public beach. The origin of contamination, unsurprisingly, appears to be from a nearby sewage treatment plant (STP).

There is a common misconception that bacterium, once exposed to sunlight, would quickly die-off. Field measurements have shown this is not necessarily true, as bacterial survivability (and even propagation) is also dependent on other factors in the general environment. These include "interferences" from other constituents (eg. oil and grease), which can negate die-off (Beder, 1992).

Hence, bacterium is an important consideration for Sg. Gombak/Sg. Klang especially in view of the recent rehabilitation initiative by the government of Malaysia to improve the water quality to Class IIB (of the National Water Quality Standards (NWQS)) (ROL, 2014). Class IIB prescribes a coliform count of no more than 400 cfu/100 mL for body contact (hence also for recreational activities). This is in-line with the intention of developing river cruises along Sg. Gombak/Sg. Klang.

One of the adopted approaches, is the centralization of sewage and sullage sources to regional (mega) STPs (Ujang and Henze, 2006). Therefore, further information regarding *E. coli* distribution and die-off in Sg. Gombak/Sg. Klang is important to achieve the stipulated objective, especially in the absence of regulatory limits.

MATERIALS AND METHODS

Sampling Regime

The study area focuses on the reaches/sub-basins where existing STPs have been identified to be upgraded in-line with the river of life (ROL) rehabilitation criteria. The rivers in question are Sg. Kerayong and Sg. Batu, aside from the main-stem of Sg. Gombak. Due to the enormity of the basin, the sampling exercise was conducted between 13 to 28 February 2013.

Grab samples were collected at 28 stations, 11 on Sg. Gombak/Sg. Klang, 6 on Sg. Batu and 11 on Sg. Kerayong as well as their respective tributaries. The locations and description of the sampling stations are shown in Table 1 and Figure 1.

Table 1 : Locations of Sampling Stations (arranged from most upstream to downstream according to basin/sub-basin (Sg. Gombak – Sg. Batu – Sg. Kerayong)

Basin/Sub-basin	Station ID	Coordinates/Description
Sg. Gombak	SG1	**Coordinates :** 03 12' 00.6" N, 101 41' 55.6"E **Description :** Most upstream station location, located prior to the Bunus STP discharge point
Sg. Gombak	SG2	**Coordinates :** 03 11' 39.7" N, 101 42' 01.9"E **Description :** Located downstream of SG1 though still upstream Bunus STP discharge
Sg. Gombak (tributary)	SPH1	**Coordinates :** 03 11 30.3" N, 101 42 05.3"E **Description :** Stream leading up to Sg. Gombak near discharge location
Sg. Gombak	SG3	**Coordinates :** 03 10' 50.7" N, 101 41 59.6"E **Description :** Ambient water sampling station, located after the discharge point (near the Bandar Baru Sentul mosque)
Sg. Gombak	SG1 (Batu)	**Coordinates :** 03 10' 16.7'' N, 101 41' 42.8'' E **Description :** Station on Sg. Gombak, prior to confluence with Sg. Batu
Sg. Gombak	SG4	**Coordinates :** 03 10' 10.6" N, 101 41 38.1"E **Description :** Ambient water sampling station, located slightly upstream

		of PWTC (near Leo Palace hotel).
Sg. Gombak	SG2 (Batu)	**Coordinates :** 03 09' 05.1'' N, 101 41' 37.0'' E **Description :** Station located after confluence of Sg. Batu and Sg. Gombak, near Jalan Parlimen
Sg. Gombak	SG5 and SG6	**Coordinates :** SG5 : 03 08 57.2" N, 101 41 42.2"E and SG6 : 03 08 48.7" N, 101 41 42.2"E **Description :** Ambient water sampling station, located post-confluence with Sg. Batu (both stations near Dataran Merdeka (Lebuh Pasar Besar)).
Sg. Gombak (Sg. Klang)	SK1	**Coordinates :** 03 08 20.9" N, 101 41 41"E **Description :** Ambient water quality station located post-confluence with Sg. Klang.
Sg. Gombak (Sg. Klang)	SK2	**Coordinates :** 03 07 28.6" N, 101 40 56.4"E **Description :** Most downstream station on Sg. Klang. Located near Taman Seputeh.
Sg. Batu	SB1	**Coordinates :** 03 13' 07.5'' N, 101 40.53.8'' **Description :** Most upstream station on Sg. Batu sub-basin. Located prior to Batu STP discharge point.
Sg. Batu	SB2	**Coordinates :** 03 12' 15.0 N, E 101 40' 34.8'' **Description :** Located downstream of SB1 and after the discharge point.
Sg. Batu (tributary)	SB3	**Coordinates :** 03 12' 06.0'' N, 101 40' 23.2'' E **Description :** Station on a tributary of Sg. Batu
Sg. Batu	SB4	**Coordinates :** 03 11' 45.0'' N, 101 40' 42.0'' E **Description :** Ambient water sampling station, located near DUKE-Jalan Ipoh crossover, (near Segambut)
Sg. Batu	SB5	**Coordinates :** 03 10' 41.7'' N, 101 40' 59.2'' E **Description :** Ambient water sampling station, located about 2 km prior to confluence with Sg. Gombak
Sg. Batu	SB1 (Gombak)	**Coordinates :** 03 10 07.3" N, 101 41 33.3"E **Description :** Station on Sg. Batu, just prior to confluence with Sg. Gombak.
Sg. Kerayong	WM5	**Coordinates :** 3° 7'24.00"N, 101°44'50.39"E **Description :** Most upstream station location on Sg. Kerayong sub-basin, located prior to the tributaries (hence discharge points).
Sg. Kerayong (tributary)	WM1	**Coordinates :** 3° 7'39.21"N, 101°46'24.36"E **Description :** Located on the first tributary of Sg. Kerayong, upstream prior to contribution from Taman Tasek Tambahan STP
Sg. Kerayong (tributary)	WM2	**Coordinates :** 3° 7'53.97"N, 101°45'47.95"E **Description :** Station located after contribution from Taman Tasek Tambahan STP
Sg. Kerayong (tributary)	WM3	**Coordinates :** 3° 7'37.55"N, 101°45'23.55"E **Description :** Ambient water sampling station, located downstream of WM2, still prior to contribution from Taman Lembah Maju STP
Sg. Kerayong (tributary)	WM4	**Coordinates :** 3° 7'37.35"N, 101°45'2.94"E **Description :** Ambient water sampling station, most downstream station on the first tributary of Sg. Kerayong. Encapsulate all STP contribution within the tributary.
Sg. Kerayong	WM6	**Coordinates :** 3° 7'46.47"N, 101°44'34.61"E **Description :** Station located on the main-stem of Sg. Kerayong, post confluence of the first tributary, though prior to contribution from Taman Maluri "C" STP.
Sg. Kerayong (tributary)	WM7	**Coordinates :** 3° 7'57.02"N, 101°44'37.73"E **Description :** Station located on the second tributary of Sg. Kerayong, inculcates contribution from Taman Maluri "C" STP
Sg. Kerayong	WM8	**Coordinates :** 3°7'37.33"N, 101°44'3.15"E **Description :** Station located shortly post-confluence of the second tributary with the main-stem of Sg. Kerayong
Sg. Kerayong	WM9	**Coordinates :** 3°6'53.34"N, 101°42'48.74"E **Description :** Located on the main-stem of Sg. Kerayong, downstream of WM8

Sg. Kerayong	WM10	**Coordinates :** 3°5'49.36"N, 101°41'49.86"E **Description :** Located on the main-stem of Sg. Kerayong, downstream of WM9
Sg. Kerayong	WM11	**Coordinates :** 3°5'42.27"N, 101°40'43.60"E **Description :** The most downstream station on the main-stem of Sg. Kerayong

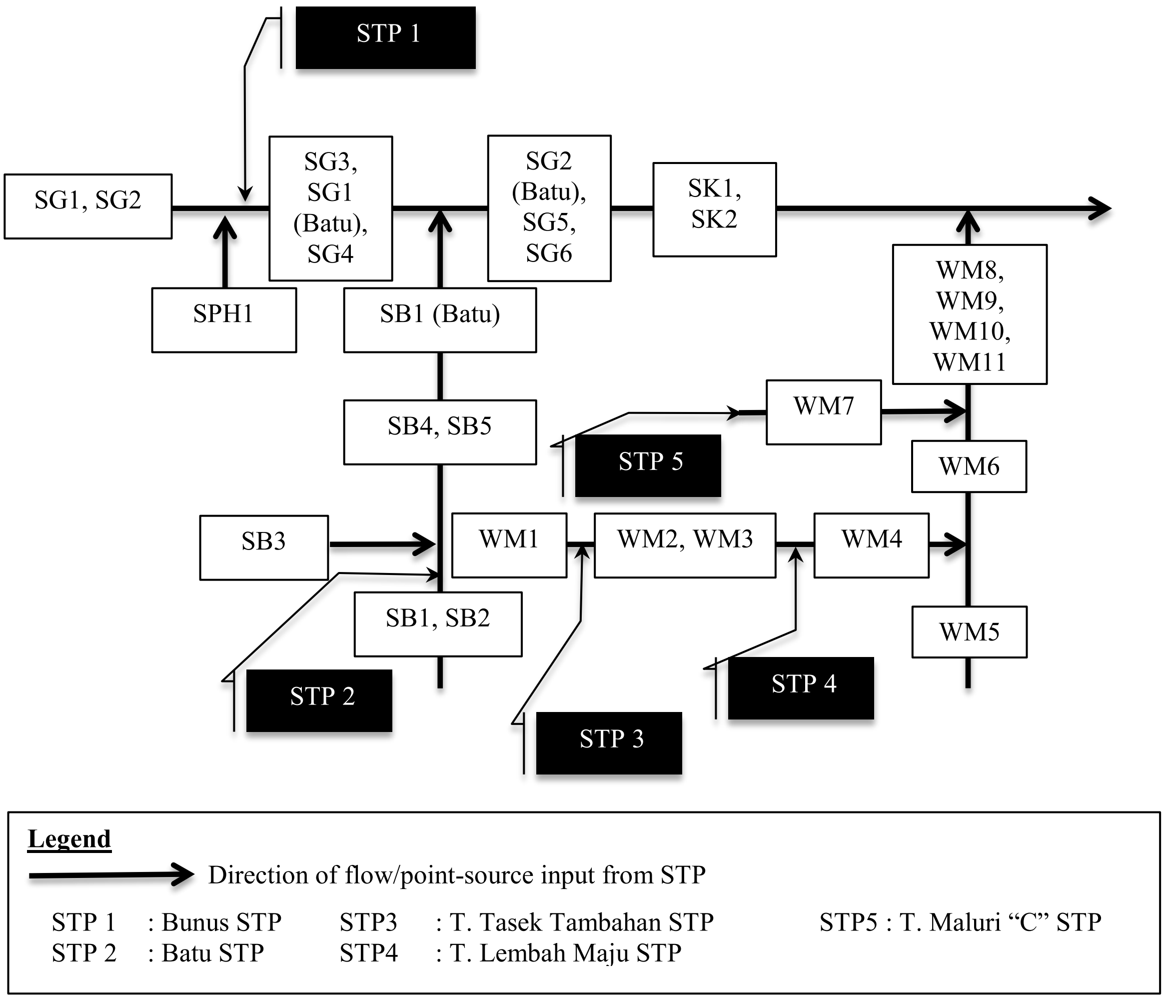

Figure 1 : Fish-bone Diagram of Location of Sampling Stations and STP Input in Sg. Gombak Basin Study Area

Measurements and Analysis

Bacterial samples were preserved and analyzed within 12 hours via the colony count method (APHA, 2005). MacConkey agar containing 1% lactose, 0.15% bile salts, and the dyes neutral red and crystal violet were used (Karim, 2011). To ensure an appropriate number of colonies were generated, several dilutions will be cultured. The laboratory procedure involves making serial dilutions of the sample (1:10, 1:100, 1:1,000) in sterile water and cultivating these on nutrient agar in a dish that is sealed and incubated.

In-situ water quality and hydraulic measurements of dissolved oxygen (DO), temperature, width, depth and velocity were made to derive travel time (Gordon et al., 2004). Besides bacterial count, analysis for biochemical oxygen demand (BOD), ammoniacal nitrogen (NH_3-N), nitrate-nitrogen (NO_3-N) and suspended solids (SS) were also done. This is to ascertain any influences these nutrients may have on in-stream *E. coli* survivability (Zainudin et al., 2010).

RESULTS AND DISCUSSION

Spatial Analysis

Referring to Figure 2, the *E. coli* count on the upper reaches of Sg. Gombak were low, less than 100 cfu/100 mL prior to input from the Bunus STP. After KM 2 (roughly where the sewage effluent enters), the levels increased significantly, in excess of 10,000 cfu/100 mL. It is, therefore apparent; the STP was a significant bacterium contributor. These levels remained relatively steady before decreasing to 1,600 cfu/100 mL mid-stream (at KM 7). This decrement can be attributed to die-off or dilution. At this location, the ambient temperature increased to above 30°C, with a ΔT rise of 4.3°C (ΔT rise; being the quantum of ambient temperature difference between the previous and current station). The levels rose again to 11,000 cfu/100 mL before subsiding to 4,200 cfu/100 mL at Sg. Klang.

Referring to Figures 3 and 4, organic (BOD), NH_3-N and NO_3-N increment appears consistent with contribution from an STP, with levels going up to 8 mg/L, 2.4 mg/L and 6.1 mg/L respectively (Zainudin et al., 2010). Degradation and oxygen uptake however, did not appear to exert a significant enough influence on the microbial count, as the populous remain fairly consistent even with variation in organic and nutrient levels.

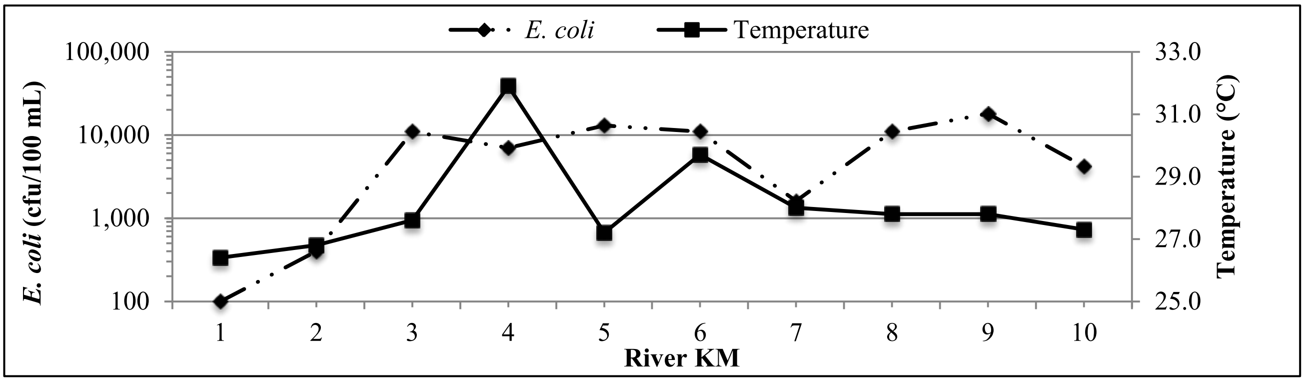

Figure 2 : Spatial *E. coli* count on main-stem of Sg. Gombak versus temperature (°C)

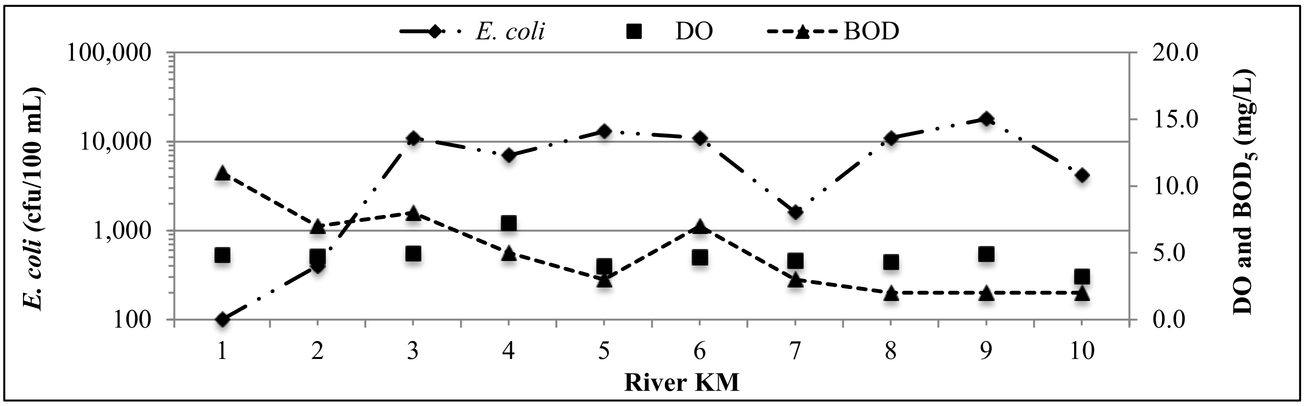

Figure 3 : Spatial *E. coli* count on main-stem of Sg. Gombak versus DO and BOD

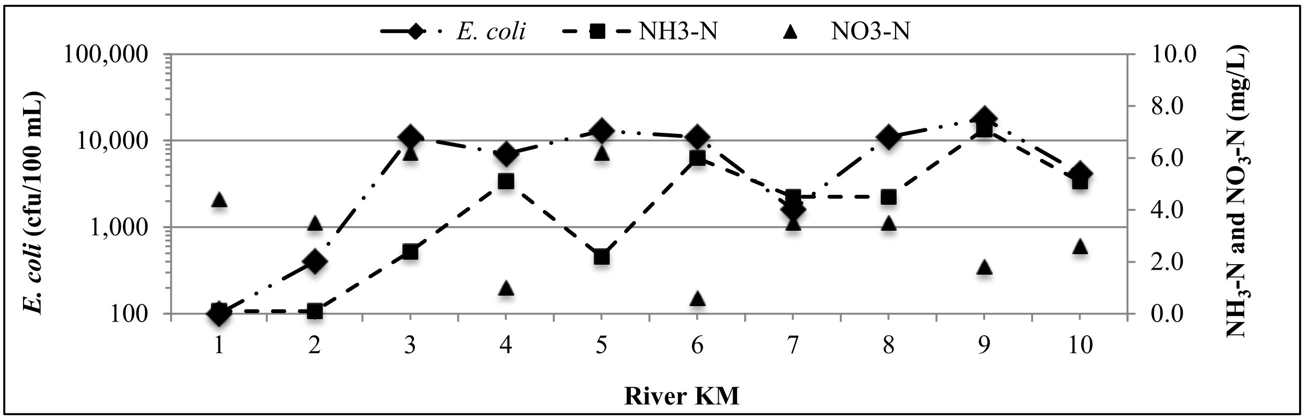

Figure 4 : Spatial *E. coli* count on main-stem of Sg. Gombak versus NH_3-N and NO_3-N

Referring to Figure 5(a), the initial count in Sg. Batu was already in excess of 15,000 cfu/100 mL upstream. Die-off (or possibly dilution) became more prevalent mid-stream, with levels decreasing to 4,500 cfu/100 mL. The decrement was accompanied by a temperature increase to 30.7°C (a ΔT rise of 3.1°C). A similar sharp die-off, from 228,000 cfu/100 mL to 68,000 cfu/100 mL, was observed in Sg. Kerayong (Figure 5(b)) when the temperature increased from 29.6 to 30.7°C. Albeit this time, the ΔT rise was only 1.2°C.

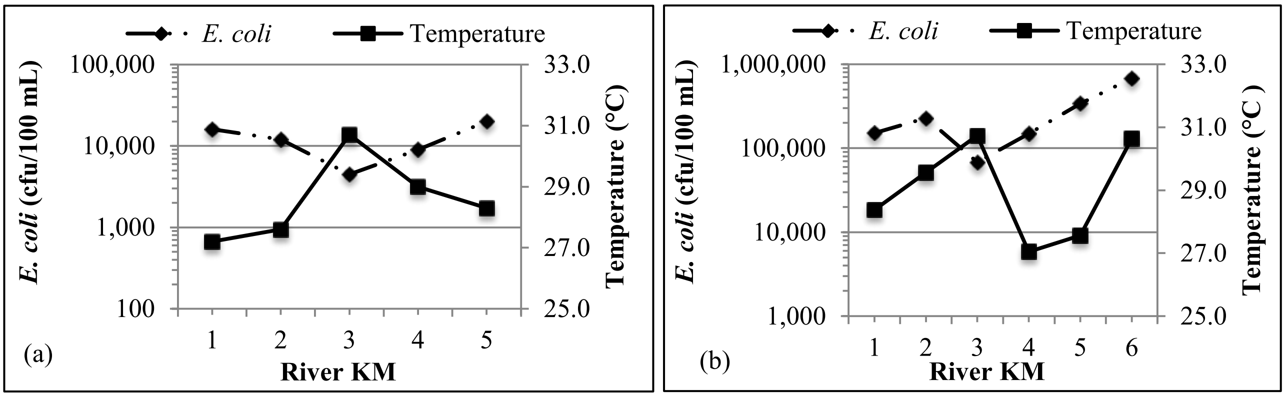

Figure 5 : *E. coli* vs temperature in (a) Sg. Batu and (b) Sg. Kerayong

At these three locations, the die-off (or decrement) per degree was 0.08/°C for Sg. Gombak, 0.20/°C for Sg. Batu and 0.64/°C for Sg. Kerayong. However, it is important to note, the decrement only becomes more prevalent when the ambient temperature extends beyond 30°C, with a ΔT rise of 3 to 4°C (with the exception of Sg. Kerayong where the ΔT rise was only 1.2°C). In-stream bacterial population appears to remains steady when the ambient temperature decreases below 29°C (irrespective of ΔT).

After these initial die-offs, the *E. coli* levels in Sg. Batu increased to 9,000 cfu/100 mL before leveling at 20,000 cfu/100 mL; whereas in Sg. Kerayong the count was in excess of 140,000 cfu/100 mL. The most downstream segment of Sg. Kerayong had a whopping count of 680,000 cfu/100 mL. *E. coli* were also elevated on the tributaries of Sg. Kerayong, with the count in excess of 80,000 cfu/100 mL (mean = 142,400 cfu/100 mL).

The results clearly illustrated *E. coli* in Sg. Gombak, Sg. Batu and Sg. Kerayong were significantly high and ultraviolet exposure did not necessarily negate the ambient count. Other factors likely inhibited the die-off (Beder, 1992). The question of insufficient die-off time should not arise, as the average travel time in all primary basins were in excess of 4 hours (Sg. Gombak = 4.969 hrs, Sg. Batu = 4.630 hrs, Sg. Kerayong = 9.818 hrs).

Microorganisms thrive in these rivers due to abundance of organics and nutrients (Metcalf and Eddy, 2004). In Sg. Batu, BOD levels were in excess of 7 mg/L and NH_3-N more than 5 mg/L. NO_3-N levels however, were relatively lower at less than 0.5 mg/L at majority of stations. The BOD supply (in excess of 15 mg/L) in Sg. Kerayong instigated a more prevalent DO depletion compared to Sg. Gombak or Sg. Batu, where levels depleted to almost anoxic conditions (Cathy, 2005; Butts et al., 1970).

Approximation of Required Ultraviolet (UV) Die-off

As suspected, the *E. coli* contribution appeared to mostly originate from STPs or other sewage sources. Since the rate of ultraviolet die-off of *E. coli* bacterium is known (Fioravanti et al., 2011; Olayemi, 1993) the average reduction required to achieve targeted levels of the NWQS can be approximated as below (Table 2). It should be noted that the reduction rates are most applicable in a controlled environment such as on-site enclosure with subsequent UV exposure rather than the general environment. The results below also include an additional safety margin of 20%. Generally, a die-off in access of 98% is required to reach 100 cfu/100 mL, which in turn translate to an exposure time of more than 2 hours. To reach 400 cfu/100 mL, an exposure time of 2 hours should be sufficient (provided all other conditions are met). These results can be used as a preliminary estimate for UV disinfection design.

Table 2 : *E. coli* Die-off Rate to Reach NWQS Standards via UV exposure

River	Class IIA		Class IIB		Class III	
	(100 cfu/100 mL) %	Time to reach (hrs)	(400 cfu/100 mL)%	Time to reach (hrs)	(5,000 cfu/100 mL) %	Time to reach (hrs)
Sg. Gombak	98.24	> 2 hrs	92.94	2 hrs	40.75	0.5 hrs
Sg. Batu	98.94	> 2 hrs	95.77	2 hrs	94.71	2 hrs
Sg. Kerayong	99.94	> 2 hrs	99.75	> 2 hrs	96.93	2 hrs

Conclusion

The study results unsurprisingly illustrate the decrepit state of the Sg. Gombak river basin. First, it is rather apparent that the discharge of sewage treatment plants significantly contributes *E. coli*. The levels in Sg. Gombak and Sg. Batu generally hovered between 11,000 cfu/100 mL to 18,000 cfu/100 mL, whereas in Sg. Kerayong, the *E. coli* levels were most of the time in excess of 140,000 cfu/100 mL. This is a direct consequence of bacterium not being regulated in the Environmental Quality (Sewage Effluent) Regulations 2009. There were occurrence of die-off (or decrement) at certain locations in the rivers, especially when the ambient temperature exceeds 30°C, with a ΔT rise of 3 to 4°C. The decrement per degree was 0.08/°C for Sg. Gombak, 0.20/°C for Sg. Batu and 0.64/°C for Sg. Kerayong. In order to achieve the aspirations of the river rehabilitation initiative, bacterial disinfection is required.

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