environments

Supplementary Materials: Determination of water quality degradation due to industrial and household wastewater in the Galing River in Kuantan, Malaysia using ion chromatograph and water quality data

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1. Average Precipitation Trend from 2000 to 2012 in Kuantan, Malaysia

In this study, we collected river water samples during low precipitation seasons to precisely assess water quality degradation due to sewage, household, and industrial wastewaters in the Galing River basin area. The average monthly precipitation trend from 2000 to 2012 indicated that January to November (139–333 mm) received relatively lower precipitation compared to December (759 mm), as shown in Figure S1. Based on the above data, our research group collected river water samples from January to November.

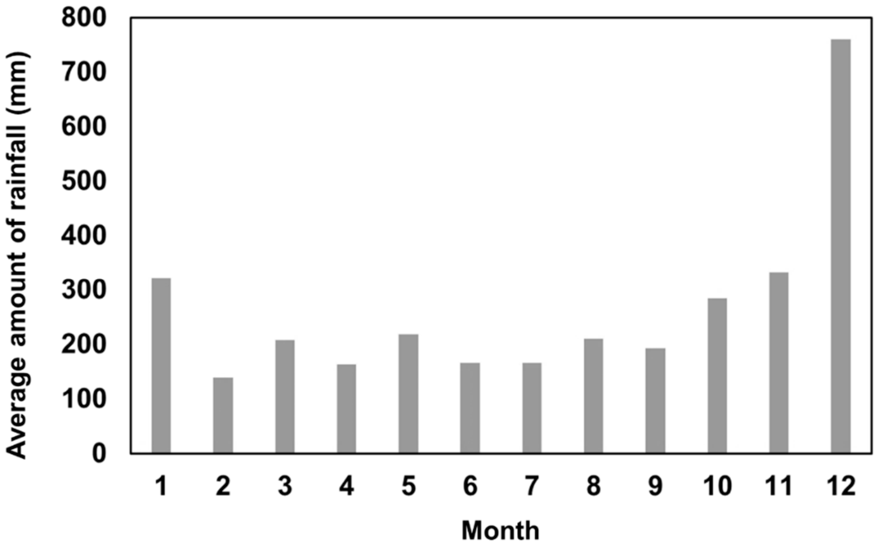

Figure S1. Average monthly precipitation from 2000 to 2012 in Kuantan, Malaysia.

2. River Water Sampling

Water samples were collected from 5 different sites during daytime on May 2014, May, August and November 2015, which recorded low precipitation seasons from 2000 to 2012 (Figure S3) [13]. The Galing River has two main tributary streams that merge into a single artery just before joining the Kuantan River. In this background research, our research group collected three samples (G1a-4, G1a-5 and G1a-6) from western side stream and two samples (G2-2 and G2-3) from eastern side stream.

All river water samples were collected at the center of the river from the surface water layer (0-15 cm from the surface). Water samples for IEC/CEC were filtered using a membrane filter (ϕ 0.45 µm; Acrodisc®–25 mm syringe filters; Pall Co., Port Washington, New York, USA) immediately following collection and injected to the IEC/CEC system. These samples were temporarily refrigerated at 6 °C. Water samples for COD and TP monitoring were temporarily refrigerated without filtration at 6 °C under dark storage [14] and immediately monitored using a UV-visible detector with reagents.

3. Comparison of Trends of Ionic Species, DO, and pH in Two Tributary Streams of the Galing River in 2015

Our research group monitored ionic species (anions: SO_4^{2-}, Cl^-, and NO_3^-, cations: Na^+, K^+, NH_4^+, Mg^{2+}, and Ca^{2+}), DO, and pH at sampling points G1 (G1a-4, 5, and 6) and G2 (G2-2 and 3) in May, August, and November 2015 to understand the variations in each parameter during a single year, as background data.

Behavior and average values of ionic concentrations, DO, and pH values in G1 and G2 are summarized in Figure S2 and Table S1 respectively. As seen in Figure S2 and Table S1, similar trends were observed for all parameters between G1 and G2 in May, August, and November 2015. For ionic species Cl^-, Na^+, K^+, NH_4^+, and Ca^{2+}, higher average concentrations were obtained from G1 compared to G2 during all monitored months, as shown in Table S1. In contrast, the concentrations of NO_3^- and DO in G1 were lower than G2. In the cases of SO_4^{2-}, Mg^{2+}, and pH, no significant differences were observed between G1 and G2.

Additionally, the average value of NH_4^+-N, DO, and pH in G1 and G2 in May, August, and November 2015 were classified according to the Natural Water Quality Standards (NWQS) for Malaysia, as shown in Table S2. Lower classifications were obtained in G1 compared to G2 in terms of NH_4^+–N (G1: class IV-V, G2: class II-IV) and DO (G1: class IV, G2: class II-III) for all the monitored months. In the case of pH, same classification was obtained in G1 and G2 (class I-II).

From the above results, immediate differences in ionic concentrations, DO, and pH were not observed from the data obtained in May, August, and November 2015. Additionally, water quality classifications in G1 were consistently lower than G2 in 2015.

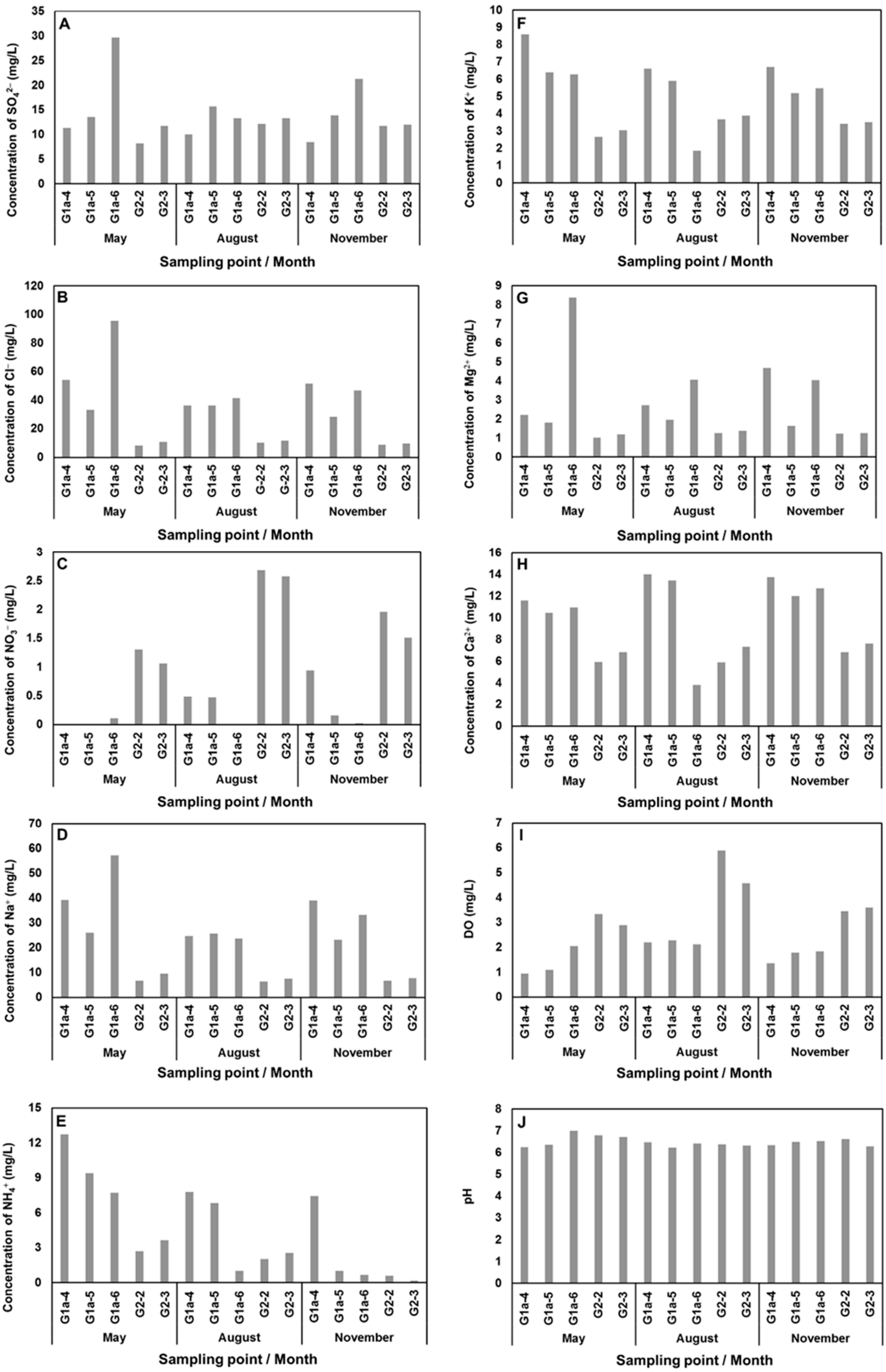

Figure S2. Behaviors of ionic species, DO, and pH in 2015.

Table S1. Average values of ionic species, DO, and pH in different tributary streams of the Galing River in 2015.

Parameter	Month	Sampling area	
		G1 (G1a-4–6)	G2 (G2-2–3)
SO_4^{2} (mg/L)	May	18.2	10.0
	August	13.0	12.7
	November	14.5	11.9
Cl (mg/L)	May	61.1	9.57
	August	38.0	10.9
	November	42.3	9.27
NO_3 (mg/L)	May	0.04	1.18
	August	0.32	2.63
	November	0.37	1.74
Na^+ (mg/L)	May	40.8	8.09
	August	24.7	6.93
	November	31.7	7.16
NH_4^+ (mg/L)	May	9.94	3.17
	August	5.21	2.29
	November	3.02	0.38
K^+ (mg/L)	May	7.09	2.86
	August	4.80	3.79
	November	5.79	3.47
Mg^{2+} (mg/L)	May	4.13	1.10
	August	2.91	1.31
	November	3.45	1.23
Ca^{2+} (mg/L)	May	11.0	6.36
	August	10.4	6.59
	November	12.8	7.21
DO (mg/L)	May	1.36	3.12
	August	2.20	5.23
	November	1.66	3.53
pH	May	6.53	6.75
	August	6.37	6.35
	November	6.45	6.45

Table S2. Water quality classification of different tributary streams of the Galing River in 2015.

Parameter	Month	Sampling area	
		G1 (G1a-4–6)	G2 (G2-2–3)
NH_4^+–N (mg/L)	May	Class V	Class IV
	August	Class V	Class IV
	November	Class IV	Class II
DO (mg/L)	May	Class IV	Class III
	August	Class IV	Class II
	November	Class IV	Class III
pH	May	Class I	Class I
	August	Class II	Class II
	November	Class II	Class II

Class I: Conservation of natural environment. Water Supply I - practically no treatment necessary. Fishery I - very sensitive aquatic species. Class II: Water Supply II - Conventional treatment. Fishery II - Sensitive aquatic species. Recreational use - body contact. Class III: Water Supply III - Extensive treatment required. Fishery III - Common of economic value and tolerant species, livestock drinking. Class IV: Irrigation. Class V: None of the above [12].

4. Comparison of Trends of Ionic Species, DO, and pH in Two Tributary Streams of the Galing River in 2014, 2015, and 2016

Our research group summarized the concentration of ionic species, DO, and pH at sampling points G1 (G1a-4, 5, 6) and G2 (G2-2 and G2-3) in May 2014, May 2015, and March 2016 to assess the differences over three years.

Behavior and average values of the ionic concentrations, DO, and pH values in G1 and G2, are summarized in Figure S3 and Table S3 respectively. As shown in Figure S3 and Table S3, similar trends were observed for all the parameters between G1 and G2 in May 2014, May 2015, and March 2016. In the cases of Cl^-, Na^+, K^+, NH_4^+, and Ca^{2+}, higher average concentrations were obtained from G1 compared to G2 for all monitored months. In contrast, the concentrations of NO_3^- and DO in G1 were lower than G2. In the cases of SO_4^{2-}, Mg^{2+}, and pH, no significant differences were observed between G1 and G2.

The average values of NH_4^+-N, DO, and pH in G1 and G2 in May 2014, May 2015, and March 2016 were classified based on the NWQS for Malaysia and summarized in Table S4. Classification results indicate that lower classifications were obtained in G1 compared to G2 for NH_4^+-N (G1: class V, G2: class III-V) and DO (G1: class III-IV, G2: class II-III). In the case of pH, similar classifications were observed in G1 (class I-II) and G2 (class I-III) in May 2014 and May 2015 but not in March 2016 (G1: class II/pH 6.10, G2: class III/pH 5.91).

As a result, immediate differences in the values of ionic concentrations, DO, and pH were not observed and water quality classifications in G1 were consistently lower than G2 during May 2014, May 2015, and March 2016.

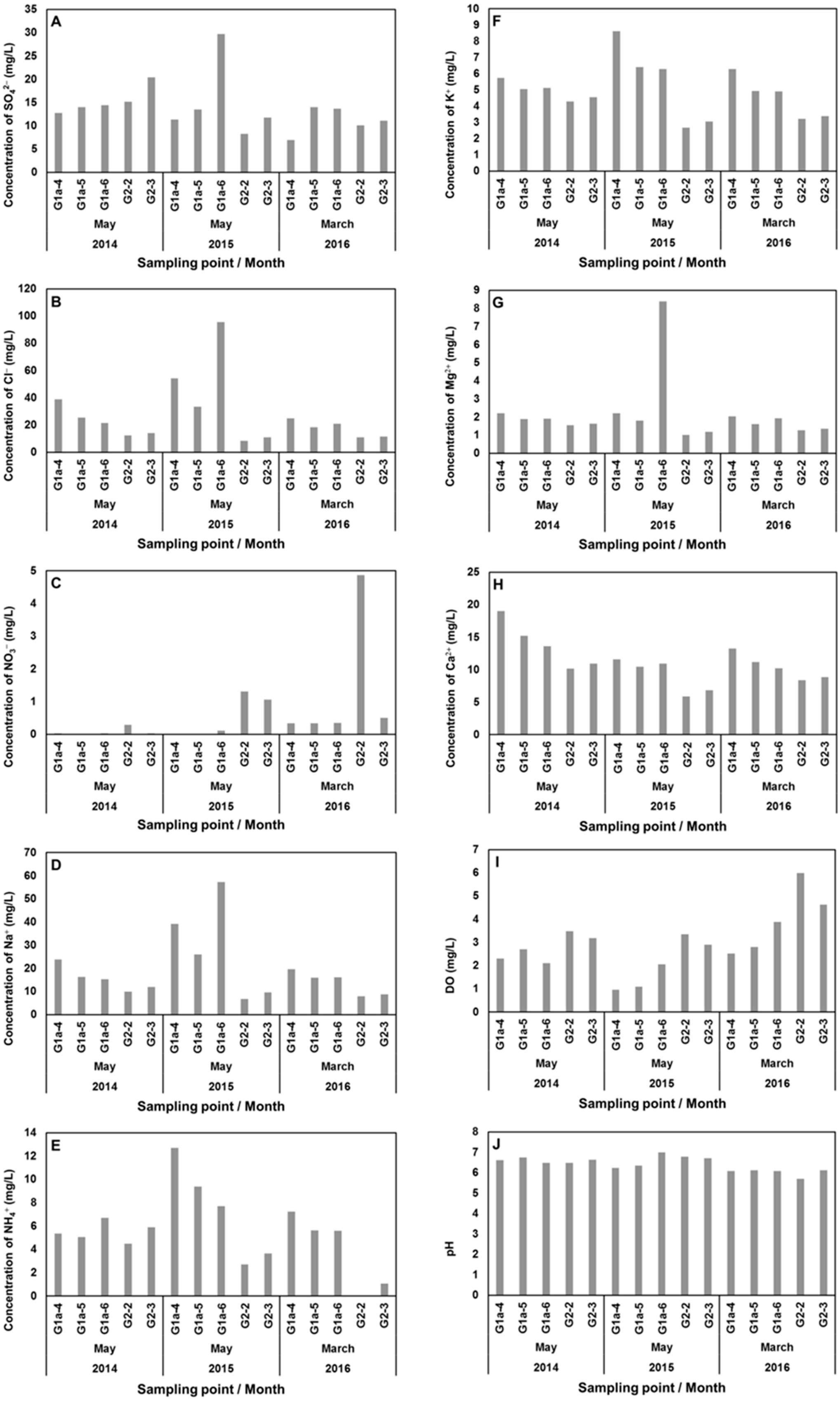

Figure S3. Comparison of the values of ionic concentrations, DO, and pH over three years in May 2014, May 2015, and March 2016.

Table S3. Average values of ionic species, DO, and pH in different tributary streams of the Galing River in May 2014, May 2015, and March 2016.

Parameter	**Month**	**Sampling area**	
		G1 (G1a-4–6)	**G2 (G2-2–3)**
SO_4^{2-} (mg/L)	May 2014	13.7	17.8
	May 2015	18.2	10.0
	March 2016	11.5	10.6
Cl^- (mg/L)	May 2014	28.5	13.2
	May 2015	61.1	9.57
	March 2016	21.4	11.2
NO_3^- (mg/L)	May 2014	0.02	0.16
	May 2015	0.04	1.18
	March 2016	0.34	2.68
Na^+ (mg/L)	May 2014	18.4	10.9
	May 2015	40.8	8.09
	March 2016	17.2	8.35
NH_4^+ (mg/L)	May 2014	5.72	5.18
	May 2015	9.94	3.17
	March 2016	6.14	0.53
K^+ (mg/L)	May 2014	5.30	4.42
	May 2015	7.09	2.86
	March 2016	5.37	3.29
Mg^{2+} (mg/L)	May 2014	2.00	1.59
	May 2015	4.13	1.10
	March 2016	1.86	1.31
Ca^{2+} (mg/L)	May 2014	15.9	10.6
	May 2015	11.0	6.36
	March 2016	11.6	8.60
DO (mg/L)	May 2014	2.37	3.33
	May 2015	1.36	3.12
	March 2016	3.07	5.31
pH	May 2014	6.61	6.56
	May 2015	6.53	6.75
	March 2016	6.10	5.91

Class I: Conservation of natural environment. Water Supply I - practically no treatment necessary. Fishery I - very sensitive aquatic species. Class II: Water Supply II - Conventional treatment. Fishery II - Sensitive aquatic species. Recreational use - body contact. Class III: Water Supply III - Extensive treatment required. Fishery III - Common of economic value and tolerant species, livestock drinking. Class IV: Irrigation. Class V: None of the above.

Table S4. Water quality classification of different tributary streams of the Galing River in May 2014, May 2015, and March 2016.

Parameter	Month	Sampling area	
		G1 (G1a-4–6)	G2 (G2-2–3)
NH_4^+–N (mg/L)	May 2014	Class V	Class V
	May 2015	Class V	Class IV
	March 2016	Class V	Class III
DO (mg/L)	May 2014	Class IV	Class III
	May 2015	Class IV	Class III
	March 2016	Class III	Class II
pH	May 2014	Class I	Class I
	May 2015	Class I	Class I
	March 2016	Class II	Class III

Class I: Conservation of natural environment. Water Supply I - practically no treatment necessary. Fishery I - very sensitive aquatic species. Class II: Water Supply II - Conventional treatment. Fishery II - Sensitive aquatic species. Recreational use - body contact. Class III: Water Supply III - Extensive treatment required. Fishery III - Common of economic value and tolerant species, livestock drinking. Class IV: Irrigation. Class V: None of the above [12].